REPORT RESUMES

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PROGRAMMING VISUAL PRESENTATIONS FOR PROCEDURAL LEARNING.
STUDIES IN TELEVISED INSTRUCTION. FINAL REPORT.
BY- GROPPER, GEORGE L.
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DESCRIPTORS- *MECHANICAL SKILLS, *VIDEO TAPE RECORDINGS,
*CLOSED CIRCUIT TELEVISION, *RECOGNITION, *DEMONSTRATIONS
(EDUCATIONAL), VISUAL STIMULI, PROGRAMED INSTRUCTION,

TWO EXPERIMENTS WITH GRADE 7 STUDENTS INVESTIGATED USE OF VIDEO TAPED, PROGRAMED DEMONSTRATIONS FOR LEARNING TO ASSEMBLE AN ELECTRICAL MOTOR. INDEPENDENT VARIABLES WERE SIZE OF DEMONSTRATION UNIT AND MODE OF PRACTICE (ACTUAL VERSUS RECOGNITION). RESULTS SHOWED THAT THE LARGER THE UNIT, THE MORE ERRORS STUDENTS COMMITTED DURING PRACTICE, AND THIS WAS SIGNIFICANT FOR LOW IQ STUDENTS, BUT AFFECTED STUDENTS IN THE RECOGNITION PRACTICE CONDITION LESS. ADDED RECOGNITION PRACTICE AND PRE-CRITERION ACTUAL PRACTICE LED TO FEWER ERRORS, AND IN EXPERIMENT 2, THE RELATIONSHIP WAS STATISTICALLY SIGNIFICANT. METHODS FOR TEACHING PROCEDURAL LEARNING WERE DISCUSSED, WITH "FORWARD ORDER" FAVORED. SUPPLEMENTARY APPENDICES PRESENT EXPERIMENTAL MATERIALS. (LH)

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FINAL REPORT

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STUDIES IN TELEVISED INSTRUCTION:

PROGRAMMING VISUAL PRESENTATIONS FOR PROCEDURAL LEARNING

NOVEMBER 1966

U.S. DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE
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BUREAU OF RESEARCH

STUDIES IN TELEVISED INSTRUCTION:
PROGRAMMING VISUAL PRESENTATIONS FOR PROCEDURAL LEARNING

Project No. 1422
Grant No. OE 5-0445-5-12-5

George L. Gropper, Principal Investigator
John Pekich
Zita Glasgow
Ruth Hughes

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AMERICAN INSTITUTES FOR RESEARCH
PITTSBURGH, PENNSYLVANIA

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INTRODUCTION

Instructional research on the use of visual media to teach procedural skills has had a long history. The Lumsdaine (5) volume on student response has collated some of the most pertinent research on film mediated procedural learning. Of particular significance is the work by Sheffield, Maccoby, and their collaborators (9,10,11,12 & 13). They investigated methods for integrating filmed demonstrations and actual practice to teach such procedural tasks as the assembly of an automobile ignition distributor. Problems that have concerned these investigators include: finding an appropriate demonstration unit size that permits the student or trainee following the demonstration to engage in relatively error free practice of the task demonstrated; finding the demonstration unit size that permits later integration of all the separate units which have been presented serially.

Problems studied by other investigators include: the effect of allowing the learner, prior to viewing a demonstration, to familiarize himself with the parts to be assembled, Wulff & Kraeling (13); the importance of the viewer angle while watching a demonstration, Roshal (8); the value of response guidance, Kimble & Wulff (4); the value of repeating examples, Lumsdaine, Sulzer & Kopstein (6); and the role of practice versus motivation in active response approaches, Michael & Maccoby (7).

Many features of the procedures used in these studies are similar to those currently used in programmed instruction. Attention was not simply confined to the design of the presentation. Rather, it quite appropriately was given to the responses to be practiced following a demonstration. While attention was paid to the selection, sequencing, and organization of stimuli and to conditions of response practice, responses to visual presentations were not, as a general rule, brought under stimulus control as completely, systematically, or continuously as is currently attempted in programmed instruction.

The work done by Gropper (1,2 & 3) in programming of televised science demonstrations shows that responses can more continuously and frequently be brought under control of demonstrational events. In these studies students acquired science concepts and principles through active practice occurring throughout entire science demonstrations. Here, following the presentation of a brief demonstration illustrating a particular concept or principle, for example, that scale readings change when objects are first weighed in air and then in water, students were required to respond, i.e., to predict what would happen in a subsequent example differing slightly from the original. Responses consisted of choices among pictorial options illustrating possible outcomes. Thus, presented with programmed visual events, students came to predict outcomes or to indicate antecedents for given outcomes. Based on this kind of systematically controlled practice, principles such as "objects weigh less in water than in air" or "a perfectly elastic body returns to its original shape when a stress is removed" were acquired. When in the presence of a visually presented problem students are able to respond appropriately (predict an outcome or identify antecedents), we may say that student responses are under control of the stimulus events. In more conventional language, we may say that the student understands the principles governing the visually presented problem.

In the Gropper studies on learning of concepts and principles, response practice was required frequently. It was required following demonstrational sequences of varying durations, though generally not over five or six minutes. Since correct responding at the end of these varying intervals was contingent on appropriate attending and observing behavior throughout this interval, it is safe to assume that, if correct responses were made at the conclusion of the interval, such observing or attending behaviors were indeed made during the interval. Thus, the attending/observing behaviors may be said to have been under the control of the visual stimulus presentation. The behaviors to be acquired (the discriminations on which concept acquisition is dependent) may be also said to have come under the control of specific detailed stimuli presented in the demonstration if, at its conclusion, correct predictions are seen to occur.

The fact that the size or duration of the stimulus unit (presented before responding is required) may be considerably longer than is usually the case in printed programs need not be a major concern. We might be concerned that, if the unit is long, student responses may not be under its control or that other than desired responses may be made. However, given the fact that the correctness a response is contingent on prior observing/attending behaviors, if a correct response is made we can be satisfied that student behavior during the presentation was appropriately under its control.

The size of the demonstrational unit is of concern only to the extent that it permits or cannot permit correct responding at its conclusion. This problem is recognized more readily in demonstrations that are intended to serve as a model for the performance of correct procedures. The demonstration unit must be short enough to permit accurate performance of the same task or procedure by the learner after he has viewed it. It also cannot be too short or else it may subsequently interfere with the final integration of separate units.

The present project is thus concerned with the development of programming techniques for designing demonstrations that will permit effective and efficient learning of procedural tasks. It seeks to identify techniques that will ensure stimulus control, not only of the attending/observing behaviors, but also of the procedural behaviors to be acquired. It is also concerned with finding ways of determining the optimum size of the demonstration unit, that is, one that will permit correct responding.

Instructional Strategies Involving Demonstrations for Two Different Types of Learning.

Strategies for teaching any kind of performance, whether procedural or conceptual, must be analytically directed to the learning tasks involved in it. It might be useful to illustrate this point by contrasting the tasks the learner faces in learning concepts and principles and those he faces in learning procedures. Their differing requirements in turn call for differing instructional strategies. And, as a result, demonstrations designed to implement the strategies may also be seen to differ strikingly from one another.

In learning concepts and principles, the student must learn to distinguish or discriminate between classes of objects, events, or ideas. He must also learn to generalize across equivalent objects, events, or ideas within a class. For example, in using levers, he learns that less applied force is required if the fulcrum is closer to the load. Understanding of this principle is based: (1) on the discrimination of the different effects of two classes of events i.e., close and distant fulcrum positions and (2) on the generalization that there are a variety of close and distant positions and also that these effects hold for a variety of levers.

If visual demonstrations are to be used to teach the relationship between fulcrum position and amount of applied force required, an instructional strategy must be formulated to permit the acquisition of the underlying discriminations and generalizations. The demonstrations thus must, on the one hand, contrast the differing effects of close and distant fulcrum positions. It must do this with varied loads, varied levers and/or varied applied forces. Thus, for generalization to occur, varied but similar examples within a class must be observed. For discrimination to occur, contrasting examples must be observed. In the Gropper studies (1,2, & 3) practice selecting pictorial options following demonstrations, options having to do with fulcrum positions or varying load sizes, etc., implemented a strategy that facilitated the acquisition of discriminations concerning contrasting events. It also allowed and facilitated generalization. This kind of practice resulted in adequate criterion performance of a similar task involving selection of appropriate pictorial options. In addition, it resulted in an adequate verbal criterion performance, i.e., the ability to state verbally that, for example, it takes less applied force to lift an object when the fulcrum is closer to it.

Let us compare the requirements for visual demonstrations that were intended to teach concepts with requirements for demonstrations designed to teach procedural skills. Consider the assembly of a three-pole electrical motor. Unlike concept learning which is concerned with classes of events and the attributes that qualify for class inclusion or class exclusion (e.g., fulcrum close to load vs. fulcrum far from load, or perfectly elastic objects vs. non-perfectly elastic objects), learning to put a particular motor together is generally concerned with singular objects and events. The parts of the motor, their location, and order of assembly are in the main not intersubstitutable. Thus, generalization within a class is not a concern here. Discriminations however must be acquired. As in all learning, discriminations are a concern but they do not involve problems of class inclusion or exclusion. The discriminations concern: the identification and selection of particular parts; the particular location in which the parts are to be assembled; and the appearance the particular assembly has when it is completed. Discriminations are between specific right and wrong parts (not substitutable classes of parts), between specific right and wrong locations, and between specific correct and incorrect orders of assembly. The closest procedural learning comes to resembling concept learning is in the discrimination between correct and incorrect assemblies and in accepting a range of variations should they exist.

Learning procedural skills, in addition to being based on acquisition of discriminations, also involves the acquisition of sequences of chained responses (putting all the parts together in correct order and manner). To teach these skills, visual demonstrations must provide the student with an opportunity to acquire the discriminations involved in the identification and selection of parts and to acquire and retain the appropriate long chains. The two studies reported here are thus concerned with a strategy and the practical techniques for programming demonstrations that facilitate such learning.

EXPERIMENT #1

A STUDY OF VARIABLES AFFECTING LEARNING FROM DEMONSTRATIONS:

Size of Demonstration Unit and Mode of Practice

This study is concerned with two interrelated issues: (a) formulation of programming techniques for designing demonstrations to teach procedural learning; (b) investigation of the effects on procedural learning of such variables as the size of the demonstration unit and the mode of student practice following the demonstration.

METHOD

Materials.

Television tapes.

Four television tapes were prepared for use in this study. All four tapes demonstrated the assembly of the three-pole electric motor illustrated below. All four had review sequences built into them. All four also had provisions for student practice in recognizing correct selection of parts, correct part locations, and correct assembly sequences. (See Appendix A for a script of the entire lesson. At various places in the script opportunities for recognition practice are provided. Workbooks providing for choices among correct and incorrect selection of parts or mode of assembly are reproduced in Appendix C.) The tapes differed only with respect to the point at which, following the demonstration (which included recognition practice), additional student practice occurred.

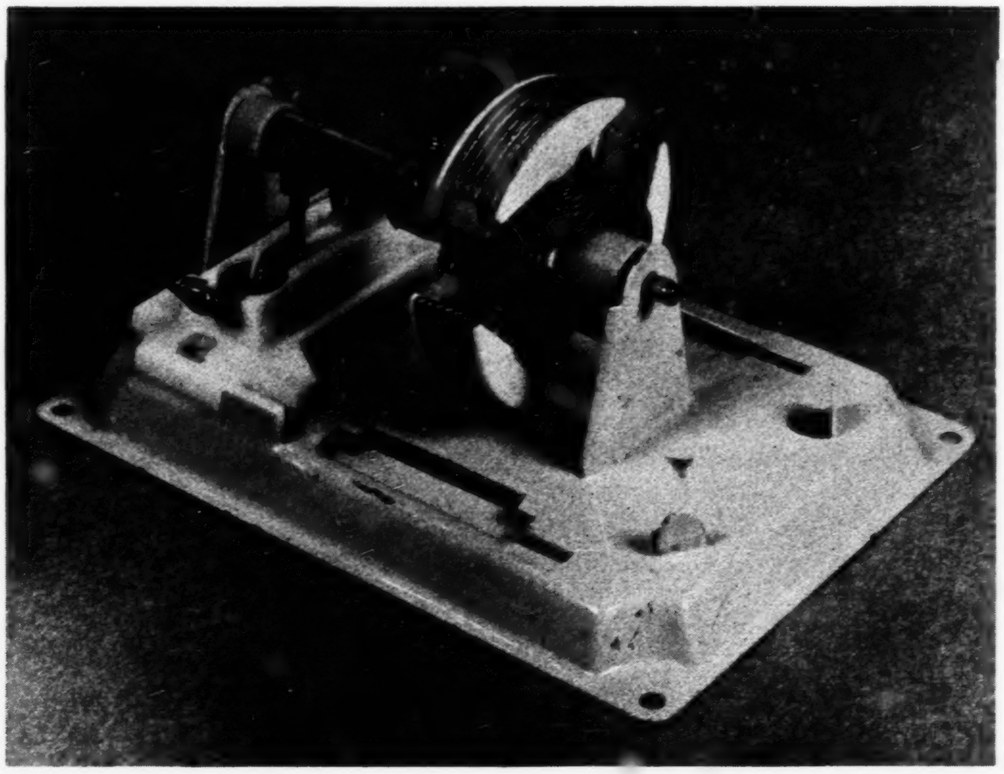


Illustration 1. Three-Pole Electric Motor

Size of demonstration unit. This study was concerned with variations in how much of a procedural task could be demonstrated before practice was allowed. The tapes were therefore designed to provide an opportunity for practice at different points in the demonstration. Tape 1 provided a practice opportunity following the demonstration of the assembly of the armature (called the "turning part" in the lesson to avoid the necessity of teaching technical names). Tape 2 provided a practice opportunity only after both the assembly of the armature and the commutator (called the "tube part" in the lesson) were demonstrated. With Tape 3, practice occurred following the demonstration of the assembly of the armature, the commutator, and the base. With Tape 4, practice occurred following the demonstration of the assembly of the three separate motor units plus the final assembly of the three units to make up the intact motor. The total amount of practice allowed was identical for all four tapes. What varied was the time of its occurrence and the size of the practice unit (corresponding to the size of the demonstration unit).

The four tapes thus represented a systematic experimental manipulation of the demonstration unit size. The portions of the procedural task that constituted a demonstration unit corresponded to self-contained units of the motor itself. The assembly of one unit could be made independently of that of another. Further, no single unit of the motor was artificially segmented in order not to interfere with student learning of its assembly. Based on initial, live tryouts, no unit was too long or complex to interfere with the subsequent assembly of the demonstrated task. These were some of the rational considerations underlying the choice of the demonstration units.

Provisions for review and practice. On each video tape, the review portions followed the demonstration and covered as many of the demonstration units as appeared on that tape. For example, on Tape 1, review followed unit 1, unit 2, unit 3, and unit 4. On Tape 2, review followed unit 1 and unit 2 combined and then unit 3 and unit 4 combined, etc. In addition to the review, which covered key steps in the assembly task, each tape had additional recognition practice built into it. (The script for this portion appears in Appendix B; the corresponding workbook in Appendix C.) The recognition practice covered only those units just previously demonstrated. This type of practice is referred to as "editing" practice. It gave the student the opportunity, based on what he had learned during the demonstration, to edit or critique the assembly demonstrated.

Mode of practice. On each tape the order of events for each unit (no matter what its size) was as follows:

---demonstration
---interspersed recognition practice
---review
---added recognition practice

Because mode of practice (practice assembling a motor vs. recognition practice) was an additional variable to be assessed, in the playback of the tape during the experiment, the tape was stopped following the review section. Students receiving this treatment then engaged in actual practice, practice in producing an assembled motor. The sequence of events for this group was as follows:

---demonstration
---interspersed recognition practice
---review
---actual assembly practice

Demonstration content. The script in Appendix A reproduces the dialogue for the entire lesson. In addition it provides photographs covering a majority of the visual events that were portrayed on the screen. The demonstration, the associated recognition practice, and the associated review segment were designed: (a) to familiarize the viewer with the parts to be selected and assembled for a particular unit; (b) to enable the viewer to determine which parts go in which location; (c) to enable the viewer to assemble the parts in an appropriate order or sequence; and (d) to enable the viewer to recognize what a properly assembled unit (or portion of a unit) looks like.

Model motor parts were used when the actual parts were too small to be shown clearly. Television techniques, such as supers, were used to stress key points. For example, an arrow super was used to indicate the correct direction in winding wire around the poles of the armature. Both review and recognition practice stressed the procedures which in the tryout phase produced the greatest frequency of errors.

Motor kits.

All the separate parts of the motor were individually taped to a large piece of cardboard. This provided an array of parts from which students had to select parts appropriate to the unit he was assembling (see Illustration 2). With the parts widely separated, students had little difficulty identifying appropriate parts and gaining access to them. The location of parts was randomized so as not to provide any clues as to which set of parts belonged together.

Workbooks.

Each demonstration included problems posed to students concerning part selection (e.g., Which parts should be selected for putting together the base?), part location (e.g., Does the tube go here or here?), andthe order of assembly (e.g., Does this part go on before this one?). Student workbooks provided multiple choice situations allowing the student to differentiate (by selection) the correct from an incorrect part and to differentiate the correct from an incorrect location or assembly order.

Appendix C presents all the workbooks used for recognition practice required during all units of the demonstration. Workbooks were used for the editing sequences that followed the demonstrations and are also included in Appendix C.

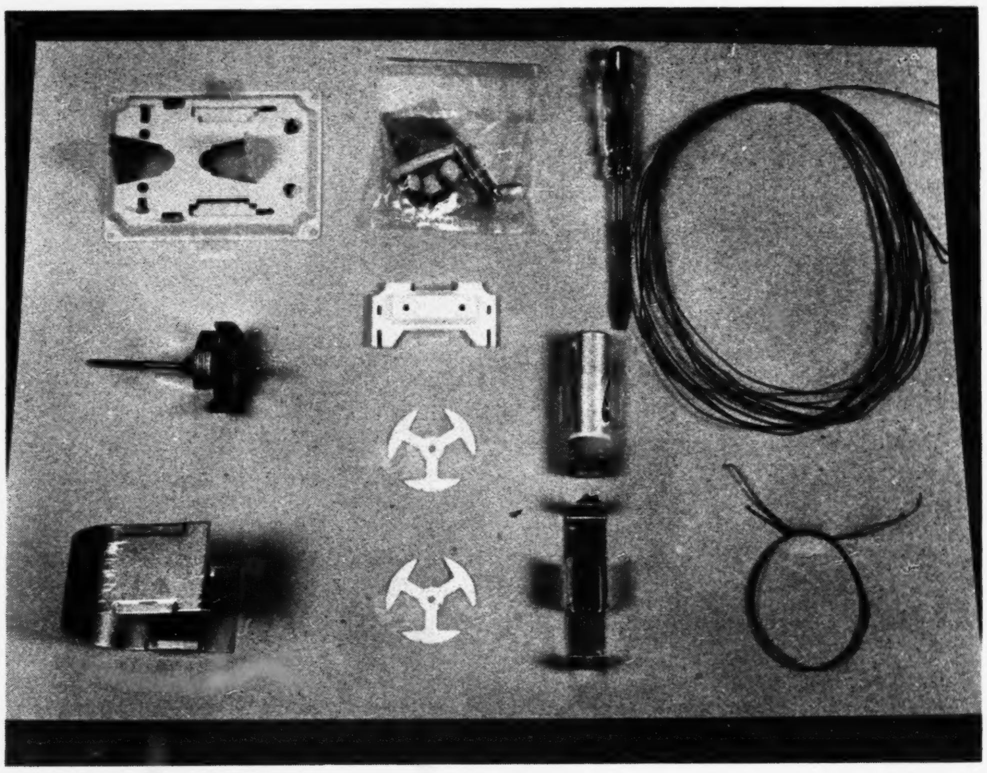


Illustration 2. Arrangement of Motor Parts Taped to Cardboard

Checklists.

Checklists, reproduced in Appendix D, were prepared for use by proctors who observed students assembling a motor. Proctors were required to record errors of omission or commission having to do with part selection and with the assembly of the motor. They were also required, when student errors were made, to provide (and record the fact) extra help or cuing. Increasingly more complete help was given if needed. Levels of help progressed from simply telling the student he was wrong, to telling the student how to do a particular step, to showing the student how to do it.

Correction was given so that students could continue the assembly task. Without correction, cumulative errors would have resulted that would not fairly reflect what students were actually capable of. The correction procedure, both in practice and criterion sessions, thus created a "practice plus feedback" treatment.

Design of the Experiment.

There were two experimentally manipulated variables: size of the demonstration unit and mode of practice. There were four levels of unit size and two levels of practice mode. This resulted in eight experimental treatments which are described below:

EXPERIMENTAL TREATMENTS

Size of the Demonstration Unit

	After Each of the Four Units		After Units 1 & 2 Combined After Units 3 & 4 Combined		After Units 1, 2, & 3 Combined & After Unit 4		After All Units Combined	
Groups	1	2	3	4	5	6	7	8
Production Practice	X		X		X		X	
Recognition Practice		X		X		X		X

Following the conduct of the experiment, two additional independent variables that were isolated and treated statistically were I.Q. (two levels) and sex (two levels). This resulted in a 4 x 2 x 2 x 2 design as illustrated below.

Size of Demonstration Unit

Type of Practice			I		II		III		IV	
			I.Q.		I.Q.		I.Q.		I.Q.	
			High	Low	High	Low	High	Low	High	Low
Active	Sex	M								
		F								
Recognition	Sex	M								
		F								

Design of the Experiment

Procedure.

The eight experimental treatments were administered on one Saturday in the television studios of WQED (channel 13), the educational television station in Pittsburgh. Students in each of the treatments sat before a television monitor. Three to five students were assigned to each monitor. Illustration 3 below depicts the physical arrangements adhered to in the studio.

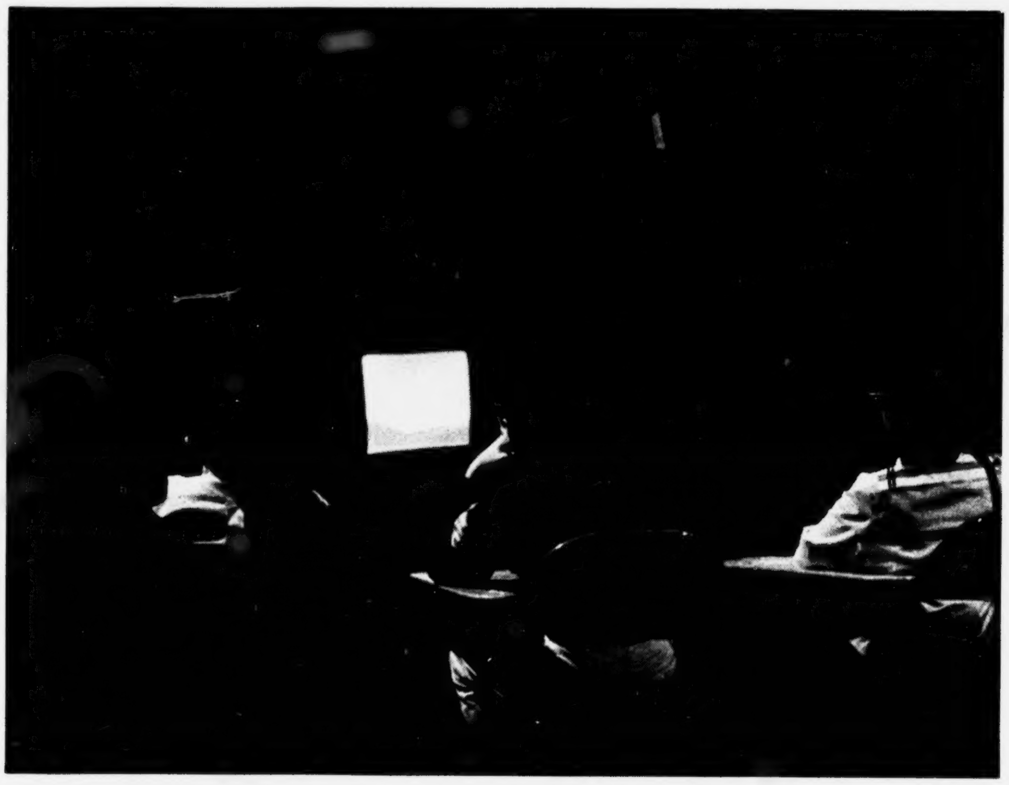


Illustration 3. Students Seated before a Television Monitor

The following instructions were given all students no matter which experimental treatment they received.

"We appreciate your volunteering to come here today. When we are finished you will all have a chance to go on a tour of the television studios.

Today we are going to show you how to put an electric motor together. We are going to show you how to do this by having you watch a television demonstration. When the demonstration is over, all of you will assemble a motor.

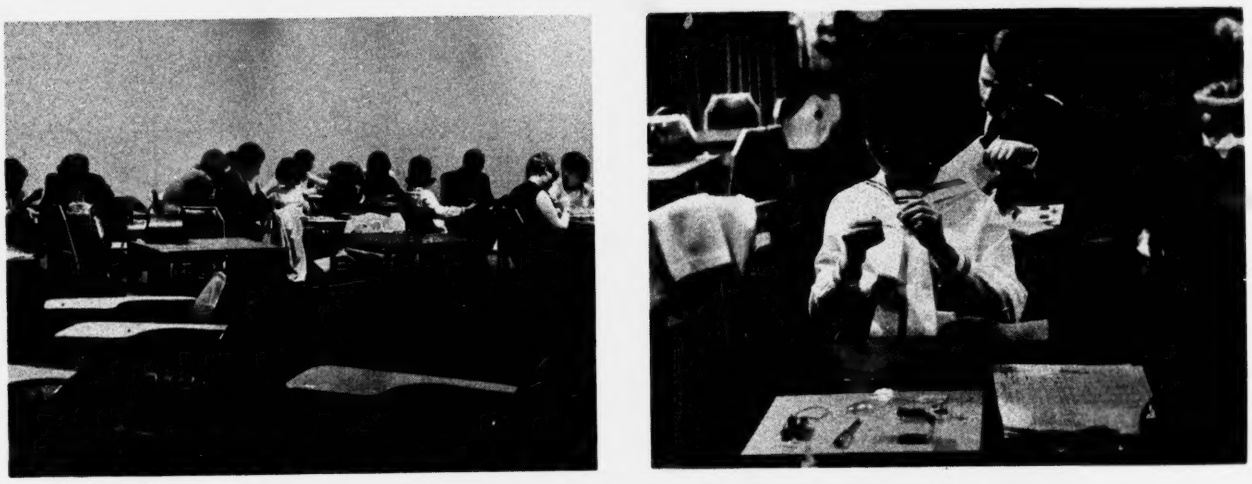
When you finish today, you will be allowed to take your motors home with you; so in order for your motor to work, you'll want to pay close attention to the demonstration and then work carefully on the motor.

The first thing we want you to do is to fill in the front cover of your workbooks. Write your name and today's date. Beside Condition - fill in the area and the time.

During the TV demonstration you will be asked to answer some questions about what you have seen. Put your answers

> in these workbooks. The instructor will tell you when to turn to a particular page. You will have plenty of time to turn to the correct page in your workbook. This is not a test. Do not open your workbooks until the direction is given to do so."

For students who engaged in recognition practice following the portion of the demonstration that was seen by all students, the tape simply continued to roll and students continued to solve problems in their workbooks. For students who were to practice putting a motor together, the tape stopped and students moved to tables. Each student worked at a separate table with his work observed by a proctor (see Illustrations 4 & 4a).



Illustrations 4 & 4a. Students Assembling
Motors at Individual Tables

A sample set of instructions delivered to these students follows:

> "Now you are going to put the turning part of the motor together. The plastic bag contains the small parts. Remove the plastic bag from the cardboard and take out the pieces you will need to assemble the turning part. Also remove any parts you will need, from the cardboard."

When these students completed all the practice rounds called for by the treatment in which they participated, they were then instructed to assemble another identical motor. Instructions were as follows:

> "The demonstrations you say helped you to put the motor together. Now we want to see if you can put a motor together without any help at all. This will be the motor you will keep. Work carefully so that all the parts will be assembled correctly. When you finish, we will go on a tour of WQED."

In the practice assembly for the production practice group and in the criterion assembly for both the recognition and production practice groups, students were permitted to work at their own pace. Proctors timed each student but also allowed them sufficient time to correct any errors they might have had. If a student failed to realize he had made an error or if he was unable to correct an error he could recognize, the proctor then provided cues, of increasing completeness (as needed) as to how he might correct his error. Illustrations 5, 6, 7, 8, illustrate the working relationship between student and proctor.

Illustration 5.

Illustration 6.

Illustration 7.

Illustration 8.

Sample.

The sample consisted of 89 boys and girls drawn from seventh-grade classes from one Pittsburgh area school. These Ss were assigned at random to one of the eight experimental conditions

RESULTS

The two major issues about which data have been collected in this study are these: (1) How does the size of the demonstration unit (before practice is allowed) affect practice when it occurs? (2) What are the effects on criterion performance of two kinds of prior practice: actual practice vs. recognition practice? Data on each of these issues will be presented in turn.

To answer the questions raised above, data are available from two sources. This may be illustrated in Figure 1.

Sequence of Activities of Experimental Groups

Groups ▼	Watched Demonstration 1	Engaged in Recognition Practice 2	Engaged in Actual Practice 3	Performed Criterion Assembly 4
actual practice	✓	A.	C. ✓	E. ✓
recognition practice	✓	B. ✓	D.	F. ✓

Fig. 1. Activities engaged in by actual-practice and recognition-practice groups.

For one group, the actual-practice group, performance measures are available for two assemblies: a practice assembly (Cell C) and a criterion assembly (Cell E). For the recognition-practice group, performance measures are available only for the criterion assembly (Cell F). Comparisions to be observed below will center, on the one hand, on the criterion performance of both groups (Cells E & F). This will provide a measure of the relative effectiveness of the two types of prior practice (Cells B & C). On the other hand, they will center on the practice performance of the actual-practice group (Cell C) and the criterion performance of the recognition-practice group (Cell F); both these cells represent the first attempt of both groups to assemble the motor. Thus, results from both Cells C and F having to do with the assembly of the motor following the demonstration provide the most immediate and direct evidence bearing on the effect that the size of the demonstration unit has on learning a procedural task.

Size of Demonstration Unit.

An analysis of variance was made for errors committed on the first assembly of the motor by both the actual-practice and the recognition-practice groups (Cells C & F). For 3/47 df an F of 2.79 is needed to be significant at the 5% level; for the 1/47 df, 4.05 is needed. The total number of errors possible in assembling the entire motor was 87. This included 39 possible selection errors (selecting the correct parts) and 48 assembly errors.

As shown in Table 1, there was a uniform increase in errors as the size of the unit increased.

TABLE 1

Mean Error Scores on First Motor Assembly for Groups Differing in Size of Demonstration Unit Observed

	Size of Demonstration Unit			
	1	2	3	4
$\bar{X}$	3.10	3.95	4.60	5.05
S.D.	2.02	2.85	2.95	4.45
N	20	19	20	20

But as can be noted in row 1 in Table 2 on page 21, summarizing the main effects in the analysis of variance, the differences in errors among the different sized units was not statistically significant. It should also be noted that even the highest error mean (5.05) for the longest demonstration unit represents an error rate of only 6%. For all Ss the error rate was 5%.

Reasons for the overall increasing error trend not being statisticially significant may be better illuminated by Figure 2, (page 22) illustrating the significant interaction that was obtained between "size of unit" and I.Q. ($P < .05$) (see row 2 in Table 2 for first order interactions). Low I.Q. Ss made more errors the longer the demonstration unit they had watched. High I.Q. Ss, on the other hand, reversed the trend and made slightly fewer errors as the size of the unit increased.

Referring back to Table 2, it can be noted, that on the assembly of the entire motor the only statistically significant finding for "errors" was the size of unit X I.Q. interaction. Time-to-complete the assembly of the entire motor provided no significant differences. The mean completion time for the whole sample was 31 minutes and the four different sized demonstration units differed only slightly from it.

The data just reported were based on the assembly of the entire motor. Additional data based on the assembly of just the commutator, the first part or unit of the motor that was demonstrated, provide additional illuminating results. The commutator was the largest and most complex unit to be assembled. The total number of errors possible in this assembly was 41, including 18 selection and 23 assembly errors. The analysis of variance of error data for just this unit are summarized in Table 3 on page 23.

TABLE 2

Summary of Analysis of Variance:
Errors on First Assembly of Entire Motor

		Source of Variance					
		Size of Unit	I.Q.	Mode of Practice	Sex	Within	
First Order Effects	df	3	1	1	1	47	
	Mean Square	8.50	18.15	4.59	10.98	7.48	
	F	1.14	2.42	---	1.47		
		Size X I.Q.	Size X Mode	Size X Sex	Mode X I.Q.	Mode X Sex	I.Q. X Sex
Second Order Effects	df	3	3	3	1	1	1
	Mean Square	26.65	14.49	18.24	29.51	8.46	.01
	F	3.56*	1.94	2.44	3.94	1.13	---
		Size X Mode X I.Q.	Size X Sex X I.Q.	Size X Mode X Sex	Mode X I.Q. X Sex	Size X Mode X I.Q. X Sex	
Higher Order Effects	df	3	3	3	1	3	
	Mean Square	4.38	4.47	8.42	1.65	11.16	
	F	---	---	1.13	---	1.49	

*Significance at the 5% level.

Two significant interactions are of interest here. One is a "size of unit" X "mode of practice" to be discussed in this section. The second is "I.Q." X "mode of practice" to be discussed in the next section.

Row 2 of Table 3 summarizing all the first order interactions reveals that the "size-of-unit" and "mode-of-practice" interaction was significant at the 5% level. Figure 3 (page 24) plots the mean number of errors involved in this interaction term. The experimentally introduced difference between the two practice groups consisted of allowing the recognition group to engage in added recognition practice. Both groups watched the demonstrations and engaged in active responding to pictorial options during the demonstrations. The actual-practice group then immediately practiced putting the motor together (Cell C in Figure 1). The recognition-practice group on the other hand had the opportunity to engage in additional practice recognizing (based on multiple choice pictorial options) correct from incorrect assemblies prior to its first assembly (Cell B in Figure 1). From Figure 3, it appears that this added practice offset to some extent the detrimental effects created by the increased size of the demonstration unit.

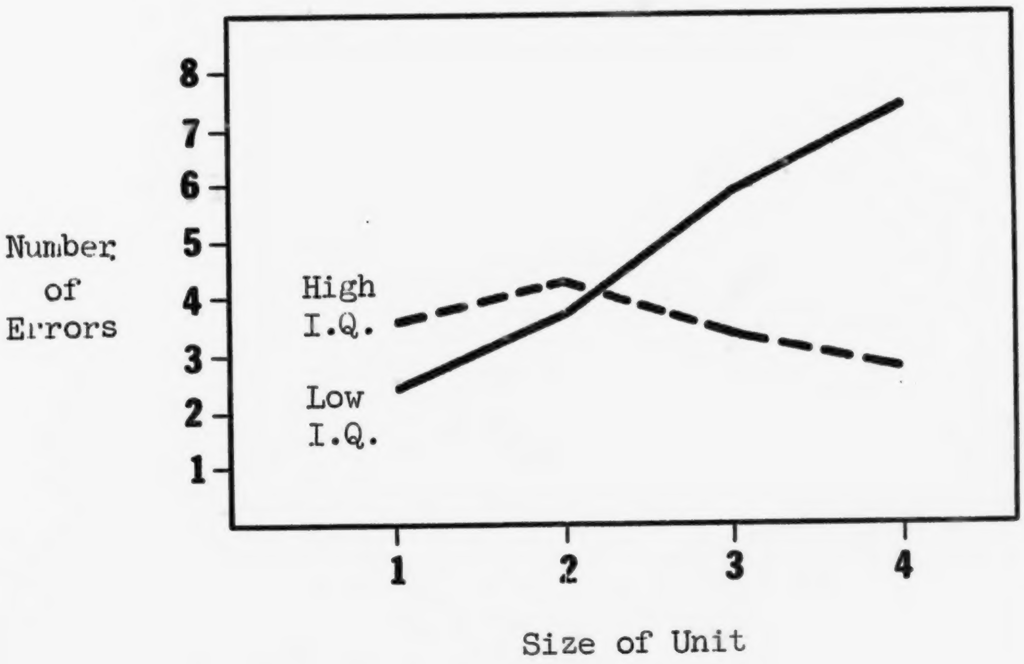


Fig. 2. Mean Error Scores on First Assembly of Entire Motor: Interaction between "Size of Unit" and "I.Q."

Results on the effect of "size of unit" may be summarized as follows:

(a) The larger the size of the demonstration unit observed before students were permitted to assemble a motor, the more errors students committed. However, the differences among groups which had watched different sized demonstration units were not significant.

(b) There was a significant interaction, however, between the "size of unit" and "I.Q." Increasing the size of the unit led to higher error frequencies in assembling a motor primarily for low-I.Q. Ss.

(c) There was also a significant interaction between "size of unit" and "mode of practice." Students who, in addition to watching and responding to the original demonstration, engaged in supplementary recognition practice tended to be less affected by the increased demonstration unit size than students who only watched the original demonstration.

TABLE 3

Summary of Analysis of Variance:
Errors on First Assembly of Commutator

		Source of Variance				
		Size of Unit	I.Q.	Mode of Practice	Sex	Within
First Order Effects	df	3	1	1	1	47
	Mean Square	4.62	13.01	1.48	.46	2.32
	F	1.99	5.60*	---	---	

		Size X I.Q.	Size X Mode	Size X Sex	Mode X I.Q.	Mode X Sex	I.Q. X Sex
Second Order Effects	df	3	3	3	1	1	1
	Mean Square	5.19	7.57	.45	17.96	2.49	.40
	F	2.24	3.26*	---	7.73**	1.07	---

		Size X Mode X I.Q.	Size X Sex X I.Q.	Size X Mode X Sex	Mode X I.Q. X Sex	Size X Mode X I.Q. X Sex
Higher Order Effects	df	3	3	3	1	3
	Mean Square	2.96	3.77	6.00	.13	1.22
	F	1.28	1.62	2.58	---	---

Significance Levels: *=5%; **=1%.

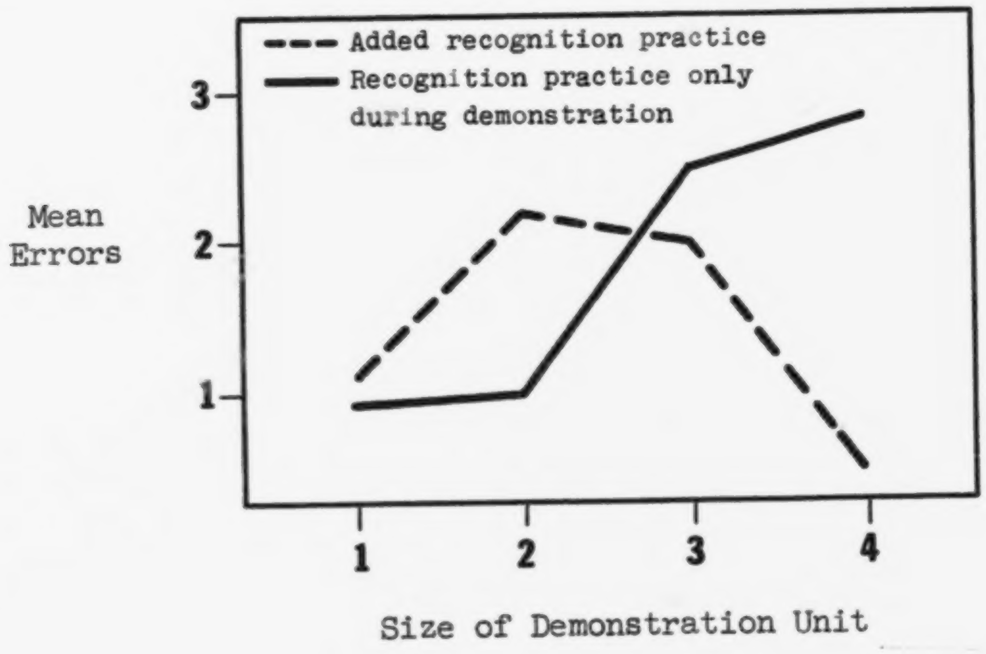


Fig. 3. Mean Error Scores on First Assembly of the Commutator: Interaction between "Size of Unit" and "Mode of Practice."

Mode of Practice.

Two questions are raised about the mode of practice:

(a) Does recognition-practice added to observation of a demonstration affect the first performance of the task demonstrated?

(b) What is the comparative effect of recognition-practice vs. actual-practice on subsequent criterion performance.

Effectiveness of added recognition practice.

We have already seen that students who, in addition to watching and responding to a demonstration of a motor assembly, had the opportunity to engage in additional recognition practice, were less affected by an increase in the size of the demonstration unit. Additionally, on the first assembly of the entire motor, the group that received added recognition-practice, made fewer errors ($\overline{X} = 3.64$, S.D. = 2.16) than the actual practice group ($\overline{X} = 4.62$, S.D. = 3.94). But, this difference was not significant (See Table 2). Table 3, however, concerned with data on the first assembly of the commutator only, reveals a significant mode-of-practice X I.Q. interaction ($P < .01$). Table 4 below provides the mean error scores for the Cells involved in this interaction. It can be noted that low I.Q. Ss who had added recognition practice made fewer errors than their low I.Q. counterparts who had merely watched the demonstration.

Relative effect on criterion performance of actual practice and recognition practice.

We are ready to compare Cells E and F in Figure 1 (page 19) which provide data on the criterion assembly of the motor. A comparison of these cells permits an assessment of the relative effectiveness of two types of prior practice: practice in assembling a motor (Cell C) and practice in merely recognizing the correctness or incorrectness of pictorially displayed assemblies (Cell B).

Errors in assembly of the motor.

Table 5 summarizes the analysis of variance for error data on the assembly of the complete motor on the criterion performance.

It will be noted in row 1 that mode of practice produces a significant main effect ($P < .001$). Table 6 presents the means for the two groups which had had different types of prior practice.

TABLE 4

Mean Error Scores on First Assembly of Commutator:
Mode of Practice X I.Q. Interaction

		I.Q.	
		High	Low
Mode	Watching Demonstration	0.9	3.1
	Added Recognition Practice	1.7	1.5

Students who had had prior practice actually assembling a motor made fewer errors on the subsequent criterion assembly than did those students who merely had prior recognition-practice.

TABLE 5

Summary of Analysis of Variance:
Errors on Criterion Assembly of Entire Motor

		Source of Variance				
		Size of Unit	I.Q.	Mode of Practice	Sex	Within
First Order Effects	df	3	1	1	1	47
	Mean Square	5.29	.52	84.58	2.94	2.86
	F	1.84	---	29.59***	1.02	

		Size X I.Q.	Size X Mode	Size X Sex	Mode X I.Q.	Mode X Sex	I.Q. X Sex
Second Order Effects	df	3	3	3	1	1	1
	Mean Square	12.44	4.11	3.31	1.83	25.50	7.32
	F	4.35**	1.40	1.16	.64	8.92**	2.56

		Size X Mode X I.Q.	Size X Sex X I.Q.	Size X Mode X Sex	Mode X I.Q. X Sex	Size X Mode X I.Q. X Sex
Higher Order Effects	df	3	3	3	1	3
	Mean Square	2.37	.73	5.77	.98	1.12
	F	---	---	2.02	---	---

Significance Levels: **=1%; ***=.1%.

TABLE 6

Mean Error Scores on Criterion Assembly of Entire Motor for Groups Receiving Different Types of Prior Practice

		Actual Practice	Recognition Practice
$\bar{X}$	=	1.62	3.64
S.D.	=	1.56	2.16
N	=	40	39

Looking at the first order interaction row of Table 5, it can be noted that there was a significant mode-of-practice X sex interaction ($P<.01$). Table 7 presents the means for the cells of this interaction. While prior recognition practice leads to more errors on criterion performance for both boys and girls, girls appear to be more handicapped by it.

TABLE 7

Mean Error Scores on Criterion Motor Assembly: Mode of Practice X Sex Interaction

		Sex	
		Male	Female
Mode of Practice	Actual Practice	2.1	1.2
	Recognition Practice	3.2	4.2

Time-to-complete motor assembly.

The relative effect on criterion performance of the two types of prior practice, actual practice and recognition practice, may be assessed by the time it took each group to complete the motor assembly. Table 8 presents mean completion time in minutes for the two groups. The group that had prior recognition-practice took more time, 7 minutes more or approximately 30% longer to assemble the motor on the criterion task than the group that had actually practiced putting another motor together. As can be noted in row 1 of Table 9, this difference was significant at the .1% level.

TABLE 8

Mean Completion Times on Criterion Motor Assembly for Two Modes of Practice

		Mode of Practice	
		Actual Practice	Recognition Practice
$\overline{X}$	=	24.48	31.71
S.D.	=	5.57	6.38
N	=	40	38

TABLE 9

Summary of Analysis of Variance: Time to Complete Assembly of Entire Motor

		Source of Variance					
		Size of Unit	I.Q.	Mode of Practice	Sex	Within	
First Order Effects	df	3	1	1	1	46	
	Mean Square	41.82	26.61	876.26	5.82	40.16	
	F	1.04	---	21.82***	---		
		Size X I.Q.	Size X Mode	Size X Sex	Mode X I.Q.	Mode X Sex	I.Q. X Sex
Second Order Effects	df	3	3	3	1	1	1
	Mean Square	9.12	.81	32.78	12.70	51.78	1.82
	F	---	---	---	---	1.29	---
		Size X Mode X I.Q.	Size X Sex X I.Q.	Size X Mode X Sex	Mode X I.Q. X Sex	Size X Mode X I.Q. X Sex	
Higher Order Effects	df	3	3	3	1	3	
	Mean Square	88.12	34.23	34.11	3.54	9.45	
	F	2.19	---	---	---	---	

*** Significance at the .1% level.

Results on "mode-of-practice" may be summarized as follows:

(1) On the first assembly of the entire motor, the group that had added recognition practice (before the first assembly) made fewer errors on the first assembly than the group that did not. This difference was not significant however.

(a) Among low-I.Q. Ss added recognition practice did lead to significantly fewer errors.

(2) On the criterion assembly of the motor, the group that had practice putting it together beforehand made fewer errors and took less time (to a statistically significant degree) than the group that had had recognition practice only.

(a) While all students who had recognition practice made more errors than the actual practice group, this effect was more pronounced for girls.

DISCUSSION

The results of the present study on procedural learning may be summarized by posing and answering three interrelated questions. Each question follows in turn.

Was the Programming Strategy Adopted Effective?

For teaching the procedural skills involved in the assembly of the three-pole electrical motor the following strategy was adopted. A model demonstration was presented that students could later imitate. Built into portions of the demonstration were discrimination practice opportunities having to do with the selection of correct parts, the correct locations of those parts, and correct assembly sequences. The strategy thus called for students to attend to and observe the model demonstration and then to practice distinguishing correct from incorrect assemblies. Were they able to assemble the motor effectively at the end of the demonstration?

Out of a possible 87 errors, the entire group obtained a mean score of 4.18 errors. Taking this value of the mean and adding to it 2 S.D.'s resulting in a value of 13.84 errors and expressing this value as a proportion of the total number of errors possible, i.e., 13.84/87, it is apparent that the approximate, maximum error rate observed was only 16%. The mean error rate was, of course, roughly a third of this value. These values are well within the range typically accepted for programmed instruction. (In practical situations, tolerable error rates, of course, depend on the consequences of making errors.)

It goes without saying, that in the absence of comparison data for some other programming strategy (varying in systematic and identifiable ways from the one used here), it is not possible to conclude that the program strategy used here was the most effective one possible. However, on the basis of the obtained results, it is reasonable to conclude that the strategy adopted was an effective one.

Did Increasing the Size of the Demonstration Unit Reduce its Effectiveness?

The demonstration of the motor assembly served as a model for students to imitate. When the demonstration included the assembly of the entire motor without pause (unit size 4), the demonstration lasted approximately one hour. Nevertheless, despite this duration students at its conclusion exhibited an assembly error rate of only 12%. The effect, however, was more pronounced for below average students than for their above average counterparts. Even though ability was measured by a largely verbal test (Otis I.Q.) the retention of visually observed procedural sequences was more greatly impaired for less able students.

While it is true that some impairment in performance was observed as the size of the demonstration unit increased for the entire group, this effect appears to have been of negligible proportions. Even though the magnitude of the effect does not appear to have been too important, in the assembly of the three-pole motor it may, however, be important to consider the potential detrimental effect that increasing demonstration unit size has. Other tasks, involving either more complex operations or a larger number of operations, may be more seriously impaired for all students as well as for less able students.

Problems in remembering a demonstrated sequence of operations that is long can be somewhat offset by additional recognition practice. With added recognition practice the assembly of the first unit was facilitated most for the group that had seen all four units demonstrated in a row before being allowed to assemble the motor. Thus, this group had an added review of the first unit that was closest in time to their actual assembly of that unit. This suggests a possible strategy that would allow lengthening demonstration unit size without performance decrement. It is conceivable that an entire demonstration could be presented and then followed with a brief review involving recognition practice. This could replace the more time consuming actual practice of individual units (followed by more demonstration and actual practice, followed by more demonstration, etc.). This is one feasible strategy for lengthening the size of the demonstration unit without impairing subsequent student performance of the procedural tasks that were demonstrated.

How Does Mode-of-Practice Affect Performance?

Performance on the first assembly of the motor was facilitated by added recognition practice occurring after the demonstration. This was particularly true for less able students, since error rates for the more able students were of almost negligible magnitude. This effect of added recognition practice was observed for the less able, it seems clear, because it was the only group that had room for improvement.

Through added recognition practice students had further opportunity to practice discriminating correct from incorrect parts, correct from incorrect placement of parts, and correct from incorrect assembly sequences. This type of practice occurring after the demonstration represented additional review and appears to have facilitated retention on the part of the less able students.

Before assembling the motor as a criterion task, one group had had prior practice (with feedback) in assembling an identical motor. A second group had merely engaged in recognition practice (with feedback). On the criterion task the actual-practice group made significantly fewer errors. But neither group made very many errors. The error rate for the recognition-practice group was 4%; for the actual-practice group it was only 2%. From a practical point of view the importance of absolute number of errors made, and, accordingly, also of the comparative difference between the two groups, depends on how critical the errors are. If highly critical, the value of actual practice assumes larger proportions. If on the other hand, errors on a task are within tolerable limits, recognition practice may be adequate. If errors are not critical, other logistical considerations such as the availability of equipment, the cost of actual practice or the time it saves may be deciding factors favoring recognition practice. It should be pointed out that the recognition practice developed here required almost as much time to complete (29 minutes) as did the actual practice (31 minutes). Whether this could be shortened remains an empirical matter. The relatively low error rates observed on the criterion task suggest that perhaps it could have been shortened.

The greater value of actual practice may be seen in the difference between the two groups in the time it took to complete the criterion assembly. The actual-practice group took approximately 25 minutes to assemble the motor; the recognition-practice group took approximately 32 minutes or thirty percent longer. Since on its first assembly or practice of the motor the actual-practice group had taken approximately as much time (31 minutes) as the recognition-practice group did on its first assembly (in this case the criterion assembly) it seems clear that actual practice facilitated the assembly of the motor. While error reduction did not reach sizeable proporations, time reduction did.

The differences between the error data and the time data require explanation. They suggest that both the actual-practice and the recognition-practice groups learned approximately equally well what to do and when to do it. But the assembly task also included a fairly lengthy motor-skill element (winding wire around the armature). A considerable portion of the assembly time was due to the winding task for the three poles of the armature. Actual practice probably "smoothed out" these motor-skill elements in the assembly task. To the extent that, in any given procedural task the motor-skill element predominates (by virtue of its length or complexity) or is at least equally demanding as the procedural or sequential elements, we may expect the benefit of actual practice to show up more clearly. Where the procedural element is paramount, recognition practice may be adequate. These speculative conclusions also require future empirical support.

The interaction between mode of practice and sex throws additional light on the role of recognition practice. While both boys and girls who had recognition practice made more errors than those who had actual practice, the effect was more pronounced for girls. Since girls are likely to have had less experience in dealing with either the procedural or motor elements involved in the assembly task, recognition practice does not appear to make up for the lack as much as actual practice. For boys, on the other hand, recognition practice, as measured by errors, appears of comparable value with actual practice. Calling for recognition practice may thus be a suitable strategy when it can capitalize or build on relevant experience.

Overall it may be concluded that actual practice is superior to recognition practice. There are circumstances, however, when recognition practice may be adequate. These might include: prior experience with the motor or procedural elements involved in a task; when the proportion of motor-skill elements in the task are minimal; or when logistical or cost considerations may preclude the use of actual equipment.

EXPERIMENT #2

AN INVESTIGATION OF THE EFFECT ON PROCEDURAL LEARNING OF MODE OF PRACTICE DURING AND AFTER DEMONSTRATIONS

The purpose of this study is to assess the effect on procedural learning of various modes of practice engaged in during and following a demonstration. This study replicates and extends the investigation begun in Experiment #1 in which production (actual) practice was found to be superior to recognition practice.

METHOD

With the exceptions to be noted below, this experiment used identical materials and followed identical procedures used in Experiment #1. The reader is, therefore, referred to the method section of Study #1 for details. Only the innovations introduced in this study will be detailed here.

Materials.

Television tapes.

One of the four television tapes used in Experiment #1 was selected for use in this study. It was the tape that allowed for added practice, either of the active, production variety or the recognition variety, only after all four units had been demonstrated. It was this tape that led to the highest error rate (compared to the other tapes but by absolute standards, an acceptable error rate). Since it produced the highest error rate, it could allow the beneficial effects of practice to be demonstrated more readily than could the other tapes. With them there would be little room for improvement.

For this experiment one new tape was prepared. It was comparable to the tape described above except that all recognition practice built into the demonstration itself was deleted. Thus, with this tape students merely watched and then were expected to complete a criterion assembly without benefit of any prior practice.

Other materials.

Workbooks, motor kits, and observer checklists used in Experiment #1 were also used in this experiment.

Design of the Experiment.

Six experimental treatments were devised for this study. They are summarized in Figure 1. Group 1 had no practice of any kind prior to the criterion assembly. Ss in this group merely watched the demonstration. This group, thus, provided a baseline against which to compare the various types of practice called for. Group 2 engaged in recognition practice with the multiple choice items interspersed throughout the demonstration. These items, identical to those in Study 1, had to do with selection, locating, and ordering the assembly of motor parts. Group 3, in addition to the recognition practice just described, engaged in recognition practice following the completion of the demonstration. Group 4, following the completion of the demonstration (including the built-in recognition practice), practiced assembling a motor.

Type of Practice Before Criterion Assembly

Experimental Groups		Recognition Practice During Demonstration	Added Recognition Practice Following Demonstration	Actual Assembly Practice	Criterion Assembly
No Practice	1				√
Recognition Practice	2	√			√
Added Recognition Practice	3	√	√		√
Recognition plus Actual Practice	4	√		√	√
Recognition plus Actual plus Added Recognition Practice*	5	√	√	√	√
Recognition plus Added Recognition plus Actual Practice*	6	√	√	√	√

*Both groups engaged in recognition and actual practice; Group 5 had recognition practice before actual practice; Group 6 had the same kind of practice but in the reverse order.

Fig. 1. Types of activity engaged in by experimental groups.

Groups 5 and 6, had all the possible types of practice: during the demonstration-recognition practice and following the demonstration both additional recognition practice and actual assembly practice. The only difference between these latter two groups was the order in which recognition and actual practice occurred following the demonstration.

Groups 2 - 6 thus engaged in different types and combinations of practice enabling an evaluation of their respective contributions.

Procedure.

Administrative details followed in Experiment 1 were also followed in this experiment.

Sample.

Fifty-one seventh graders from two schools in the Pittsburgh area participated in this experiment. They were randomly assigned to the six experimental conditions of the experiment.

RESULTS

In analyzing the effects on the criterion motor assembly of the various types of prior practice, "time-to-complete" and "errors" served as the critical dependent variables. Tables 1 and 2 summarize the results.

TABLE 1

Mean Number of Errors on Criterion Motor Assembly for Groups Receiving Different Types of Practice

Groups		$\bar{X}$	S.D.	N	Error Rate
No Practice	1	3.88	3.09	8	4.5%
Recognition Practice During Demonstration	2	6.38	4.98	8	7.3%
Recognition Practice + Added Recognition Practice	3	4.67	3.24	9	5.4%
Recognition + Actual Practice	4	1.00	1.00	9	1.1%
Recognition + Added Recognition + Actual Practice	5	1.50	2.00	8	1.7%
Recognition + Actual + Added Recognition Practice	6	1.89	4.28	9	2.2%

An analysis of variance based on the error data revealed significant differences among the treatment groups (F=4.54, which for 5/39 df is statistically significant at the 1% level). There were no statistically significant differences among groups 1, 2, and 3 which had either no practice or only recognition practice. These groups, however, did make more errors than groups 4, 5, and 6 (although not all individual comparisons were significant). These latter three groups all had practice assembling a motor before they undertook the criterion assembly.

But among groups 4, 5, and 6, all of which had actual practice in assembling a motor, there were no statistically significant differences.

It should be noted (see Table 1) that even among groups 1, 2, and 3, which made the most errors, none reached a mean error rate of 10%.

Time-to-complete the motor assembly provides more telling results in comparing the first three with the last three groups. As can be noted in Table 2, even the smallest difference found between the fastest group among the first three groups (Group 1) and the slowest among the last three groups (Group 4) was approximately seven minutes.

TABLE 2

Mean Time-to-Complete the Criterion Motor Assembly for Groups Receiving Different Types of Practice

Groups		$\bar{X}$	S.D.	N
No Practice	1	30.38	5.58	8
Recognition Practice During Demonstration	2	36.62	11.98	8
Recognition Practice + Added Recognition Practice	3	33.11	8.28	9
Recognition + Actual Practice	4	23.22	7.61	9
Recognition + Added Recognition + Actual Practice	5	22.50	5.07	8
Recognition + Actual + Added Recognition Practice	6	21.00	5.89	9

As in the case of errors, significant differences were found among the groups (F=5.38, which for 5/39 df is statistically significant at the 1% level). Also, as in the case of errors there were no significant differences among the first three groups or among the last three groups. Unlike the error analysis, however, each of the first three groups took longer than any of the second three groups; these time differences were statistically significant. These differences in mean times ranged from 7.16 to 15.62 minutes.

DISCUSSION

The findings reported here have paralleled those reported in Study #1. As compared to recognition practice, actual practice in the motor assembly resulted in significantly fewer errors. The lowered error rate was statistically significant. In practical terms, error rates were low no matter what type of prior practice students engaged in or, for that matter, whether they engaged in any practice at all. Merely watching the demonstration, and in this experiment it was a lengthy one, with the entire motor assembly demonstrated before criterion assembly was allowed, enabled students to assemble a motor with relatively few errors.

Completion times also revealed statistically significant differences between recognition-and actual-practice groups (as they had in Study #1). The magnitude of the differences appears to have practical significance as well. The slowest of the actual-practice groups took approximately 23% less time on the criterion assembly than did the fastest groups that had not engaged in actual practice.

The contrast between error and time data invites explanation. The low error rates for all treatment groups suggest that the demonstration (with or without recognition practice) adequately prepared students to select the right parts, to put them in the right places, and to assemble them in the right order. Thus, on the basis of the demonstration alone students learned to identify the correct parts, their correct location, and the sequence or order in which they were to be assembled. What merely watching the demonstration appears not to have done was to give them the motor facility in doing all these tasks. The contrasting time data suggest this interpretation. Actual practice appears to facilitate the generally time consuming motor component of a procedural-motor task. Indeed, discrepancies between time and error data may be diagnostic of the relative importance of the motor and procedural components.

The demonstration alone, even minus any kind of recognition practice, appears to have been sufficient to teach the procedural component in the motor-assembly task. Just how much recognition practice can add could not be adequately shown in this study. For, even using the demonstration tape showing all four units assembled before assigning the criterion task, presumably the most difficult task that could be assigned, resulted in low error rate. In Study #1, the value of recognition in offsetting the negative effects of increasing unit size were duly noted. But even there, the effects were small (due no doubt to reduced margins for improvement). To determine what kind of contribution recognition practice can make will require either a longer or a more complex (or both) procedural task. For, only as the limits of a demonstration alone to teach procedures are reached, can the facilitating effects of recognition practice be more adequately assessed. Thus, in order to assess the contribution to procedural learning (as opposed to learning of the motor components of a task) of either recognition or actual practice, a procedural task should be found which taxes the capability of a demonstration more sharply than did the assembly of a three-pole electric motor.

To answer the research question about the relative contribution of actual vs. recognition practice, the assembly of a three-pole electric motor may not have been long or complex enough. But, it was not an easy task. It is reassuring to note that a well-prepared demonstration, concentrating on part identification, recognition of correct part locations, and recognition of correct assembly sequences, could teach such a task. Its adequacy was attested to by the failure of added recognition practice to produce heightened achievement results.

Of considerable help in accomplishing the teaching goal in this study was the patent interest of seventh graders in the motor-assembly task. The promise of an electric motor at the end of the experiment resulted (as noted by observation of student behavior) in heightened attention to the demonstration. Even the longest of the experimental treatments resulted in no obvious fidgeting often found in experiments devoted to the learning of science concepts and principles. This kind of consistent attending and observing behavior may be a key factor in allowing a well prepared demonstration, even one that requires no active responding (of either the recognition or actual variety), to teach a procedural task adequately. It does appear, however, on the basis of the two experiments reported here, that, even with heightened motivation, actual practice is needed to reduce the time requirements involved in performing newly learned motor tasks.

Future research would do well to single out the motor and procedural components of any given procedural-motor task as a means of determining the contribution that various types of practice contribute to each. This, as was suggested above, will have to be done in the context of specific tasks that tax the capability of a demonstration alone to teach either component.

CONCLUSION

The two studies reported in this volume represent a natural progression or evolution from earlier studies in film mediated procedural learning. In earlier studies active student response was a frequent requirement. In the present study, many features of the behavioral technology represented in programmed instruction were employed. Active student response was, of course, one of them. However, more attention was paid to the ways of bringing students' attending/observing behavior, as well as the behavior to be learned, under the control of the demonstrational events. In addition, the learning task was analytically investigated beforehand, and opportunities were identified and provided in order to facilitate student acquisition of the discriminations necessary for successful learning and performance of the procedural task. Tryout and revision (prior to television taping) also were used in the present study.

The techniques and procedures used in the present study resemble those used in varied types of programmed instruction, perhaps more than those found in studies on film mediated procedural learning. However, they deviate in one respect from programmed efforts and are more like the earlier film studies. In some programmed efforts, procedural learning, involving long chained responses, tends to be taught in a backward order. The student learns the last step first, then the last two steps, the last three, the last four, and so on. Thus, when a newly learned step is performed it is always followed by an already learned step which serves to reinforce it. In the present study, the motor assembly was demonstrated in the order it was expected to be learned and performed.

It makes little sense to compare two different programs attempting to teach the same thing. The outcome depends on how well each was programmed to begin with. The comparison can be made only if one program is a variant of the other, with the variation identifiable in specific ways. Thus, if the same demonstration could be presented, with only the order of events changed, the forward and backward programming apporaches might be assessed. It might be possible to do this. For the moment, however, a few rational points, with speculation an admitted component, can be made.

As was pointed out above, one of the key features of backward chaining, is the reinforcing and confirming nature of the already learned step. In the demonstrations prepared here, before actually assembling a motor, students were given practice in recognizing what crucial completed steps look like. Thus, when they assembled a part or parts of the motor, they presumably knew whether they had performed the assembly correctly (and the correct assembly could reinforce/confirm their responses).

Prior discrimination practice concerning correct assembly characteristics can thus serve functions performed by the last learned step in the backward chaining approach. Are there other rational considerations (subject to empirical verification) that might favor the "forward order" demonstration? Some theoretical and logistical considerations do suggest themselves.

In mathetics, the term "operant span" is applied to describe the length of the learning unit that can be handled by the learner, that is, that enables him to respond correctly. An optimal training strategy is one that exposes the learner to as big an operant span as he can handle. The less cued his performance, the more he is "stretched" and the more likely he is to respond adequately to uncued criterion situations. The first study in this volume has amply indicated that the forward order demonstration of the entire motor assembly adequately prepared most students to assemble the entire motor with relatively few errors. Thus, by simply watching a demonstration and with some recognition practice the student can be assigned the largest possible operant span. In the backward chaining approach, the entire procedure must, by regulation, be broken up into several steps, so that each learned step can confirm the preceding step.

One practical consequence of the apparent requirement of the resulting, smaller operant span in backward chaining is the necessity to practice steps over and over again (with the last step practiced the most, the next to last step practiced the next most often). This can result in greater time requirements than is the case in the forward learning sequence, where, as was the case here, one practice trial was sufficient.

Both the forward and backward approaches have the means to reinforce/confirm the procedural elements (choosing, locating, and ordering parts) in a procedural-motor task. Neither appears to have an edge over the other in reinforcing/confirming the motor-skill elements in such a task. There may be a variety of ways to hold or move your hands and to get the job done, the correct assembly may not reinforce the most efficient motor pattern. Discrimination practice for this component may be a requirement for either approach (forward or backward). If not used in the backward approach, the unit or operant span might have to be made even smaller to reinforce specific motor patterns.

On the basis of the findings presented in this study, it appears that programmed, forward-order demonstrations can effectively and efficiently teach procedural-motor tasks. Final judgment on issues raised here and the verdict reached on such demonstrations will depend on careful and more detailed identification of characteristics of various types of procedural tasks and the instructional strategy best suited to, what may be qualitatively different, procedural learning tasks.

SUMMARY

Two experiments were performed for this project on the use of programmed demonstrations for procedural learning. The first experiment was concerned with two interrelated issues (a) the development of programming techniques for designing demonstrations to teach procedural learning; (b) the investigation of the effects on procedural learning of such variables as the size of the demonstration unit and the mode of student practice following the demonstration. The second study replicated and extended the investigation of the relative effectiveness of alternative modes of practice during and following demonstrations.

In both experiments seventh-grade students learned to assemble a three-pole electrical motor after having watched a video-taped demonstration. Each demonstration was programmed so as to teach students correct part selection, part location, and part assembly. The learning experience included: watching a televised demonstration; practice during the demonstration, recognizing how to assemble the motor on the basis of multiple choice pictorial options; watching review sequences; following the demonstration, either additional recognition practice or practice actually assembling a motor. All students assembled a three-pole motor as a criterion performance.

Results of Experiment #1.

Size of the demonstration unit.

(a) The larger the size of the demonstration unit observed before students were permitted to assemble a motor, the more errors students committed. However, the differences among groups which had watched different sized demonstration units were not significant.

(b) There was a significant interaction, however, between the "size of unit" and "I.Q." Increasing the size of the unit led to higher error frequencies in assembling a motor primarily for low-I.Q. *Ss*.

(c) There was also a significant interaction between "size of unit" and "mode of practice." Students who, in addition to watching and responding to the original demonstration, engaged in supplementary recognition practice tended to be less affected by the increased demonstration unit size than students who only watched the original demonstration.

Mode of practice.

(1) On the first assembly of the entire motor, the group that had added recognition practice (before the first assembly) made fewer errors on the first assembly than the group that did not. This difference was not significant however.

(a) Among low-I.Q. Ss added recognition practice did lead to significantly fewer errors.

(2) On the criterion assembly of the motor, the group that had practice putting it together beforehand made fewer errors and took less time (to a statistically significant degree) than the group that had had recognition practice only.

(a) While all students who had recognition practice made more errors than the actual practice group, this effect was more pronounced for girls.

Programming strategy employed.

It goes without saying, that in the absence of comparision data for some other programming strategy (varying in systematic and identifiable ways from the one used here), it is not possible to conclude that the program strategy used here was the most effective one possible. However, on the basis of the obtained results, it is reasonable to conclude that the strategy adopted was an effective one.

Results of Experiment #2.

The findings reported here have paralleled those reported in Study #1. As compared to recognition practice, actual practice in the motor assembly resulted in significantly fewer errors. The lowered error rate was statistically significant. In practical terms, error rates were low no matter what type of prior practice students engaged in or, for that matter, whether they engaged in any practice at all. Merely watching the demonstration, and in this experiment it was a lengthy one, with the entire motor assembly demonstrated before criterion assembly was allowed, enabled students to assemble a motor with relatively few errors.

Completion times also revealed statistically significant differences between recognition-and actual-practice groups (as they had in Study #1). The magnitude of the differences appears to have practical significance as well. The slowest of the actual-practice groups took approximately 23% less time on the criterion assembly than did the fastest groups that had not engaged in actual practice.

Two contrasting approaches for teaching procedural learning were discussed: (a) backward chaining; and (b) learning procedures in a forward order on the basis of demonstration. A key feature of the backward chaining approach is the possibility of the last learned step providing confirmation for the practice of the procedural step before it. It was pointed out that in forward order learning of procedures, discrimination practice with what a correct assembly looks like makes it possible to provide the same kind of confirmation at the completion of a step.

It was suggested that future research would do well to single out the motor and procedural components of any given procedural-motor task as a means of determining the contribution that various types of practice contribute to each.

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OFFICE OF EDUCATION
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15. ABSTRACT (250 words max.)

Two experiments were performed in this project concerned with the teaching of procedural learning by means of visual demonstrations. Television tapes were prepared to teach seventh graders how to assemble a three-pole electric motor. Students watched the demonstration, answered multiple-choice recognition questions in workbooks during and after the demonstration, watched review demonstrations, and engaged in practice assemblies. Results on research issues were as follows: increasing the size of the demonstration unit that students must watch before being allowed to assemble a motor leads to more errors, particularly for students of below average ability; the detrimental effects of increased unit size can be offset somewhat by allowing students to practice (at the recognition level) differentiating correct from incorrect assemblies; and criterion performance on the motor assembly, whether assessed in terms of errors or time-to-complete, was facilitated more by actual practice than by recognition practice. It was generally concluded that the programming techniques developed for visual demonstration effectively taught a procedural learning task. The approach used consisted in providing a model demonstration and in addition allowing students to discriminate between correct and incorrect part selection, part locations, and part assemblies.

16. RETRIEVAL TERMS (Continue on reverse)

programmed instruction
visual demonstrations
procedural learning
response practice
size of demonstration unit
mode of practice

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EM004059 A

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FINAL REPORT

Project No. 1422
Grant No. OE 5-0445-5-12-5

STUDIES IN TELEVISED INSTRUCTION:

PROGRAMMING VISUAL PRESENTATIONS FOR PROCEDURAL LEARNING

SUPPLEMENTARY APPENDIX

NOVEMBER 1966

U.S. DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE
OFFICE OF EDUCATION
BUREAU OF RESEARCH

AIR-E61-11/66-FR

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SUPPLEMENTARY APPENDIX

George L. Gropper, Principal Investigator
John Pekich
Zita Glasgow
Ruth Hughes

NOVEMBER 1966

AMERICAN INSTITUTES FOR RESEARCH
PITTSBURGH, PENNSYLVANIA

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APPENDIX A

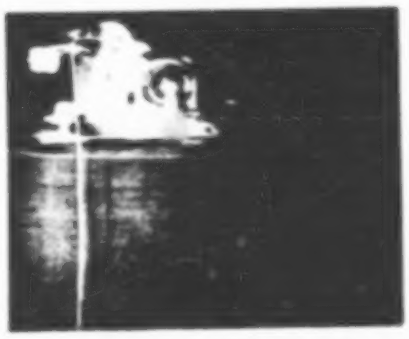
PROGRAMMING PROCEDURAL LEARNING

Script for
Assembling a Motor

Page

A. Armature Assembly A-1
B. Armature Assembly Review. A-10
C. Commutator Assembly A-12
D. Commutator Review A-17
E. Base Assembly A-18
F. Base Assembly Review. A-24
G. Connecting the Motor Parts. A-25
H. Connecting the Motor Parts Review A-32

ARMATURE ASSEMBLY



- This crane is being turned by a motor.

- Today you are going to learn how to put this kind of motor together.
- At the end of the demonstration that you are going to see, each one of you will put a motor together.
- A major part inside this motor is the part that turns.

- This is what the turning part looks like when it is taken out of the motor.

- Before you can put this big turning part together, you have to be able to recognize all these small parts that go into it.
- There is some wire which is wrapped around here.
- This is what the wire will look like before you put it on the turning part.

- There are two small tubes, one on this side and one on this side. This is what the small tubes will look like before you put them on the turning part.

- There are two large wheels, one on this side and one on this side.

- This is what the large wheels will look like before you put them on the turning part.

- And there is a rod like this with metal parts on it.

- Let's see if you can pick out the small parts that make up the turning part of the motor.

  Turn to page A-1 in your workbook.

  Put an X below the picture that shows the small pieces that make up the turning part of the motor.

- You should have put an X below picture B.

- Now let's see how these parts are put together.

  Let's see how they are assembled to make the turning part.

- The first thing to do is to straighten the three long wires. Remove any kinks or knots from them.

- With a small piece of sandpaper, scrape the coating from each end of the wire like this.

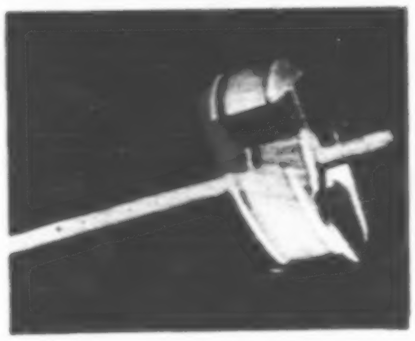
- When you finish, about one inch of each end of the wires should be shiny and should look like this.

- When you finish doing this with all three wires, place the wires on the table.

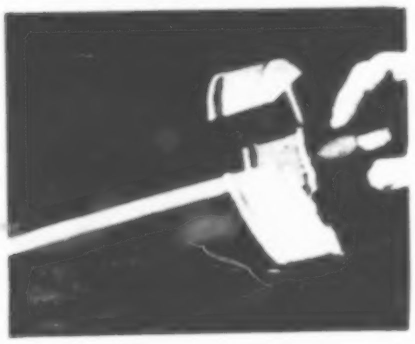
- Because the metal rod is so small, let's use this large model to get a better view of how the parts are put together.

  First, take one large wheel and put it on one side of the metal rod like this.

- Then take the other large wheel and put it on the other side of the rod, like this.

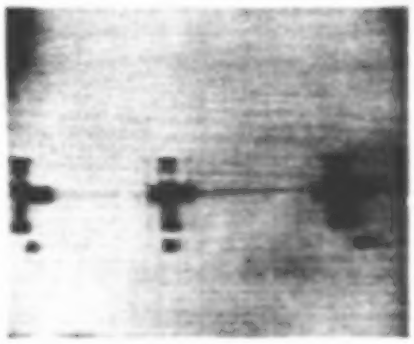


- This is what it looks like when the large wheels are put on the right way.

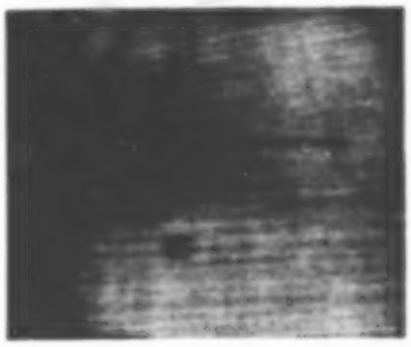


- Next, take one small tube and put it right next to the large wheel on one side, like this.

- Then take the other small tube and put it right next to the large wheel on the other side of the rod like this.



- Turn to page A-2 in your workbook. Put an X below the picture that shows how the large wheels and small tubes should be put on.



- You should have put an X below picture C.
  On each side, there should be a large wheel and a tube like this.

- Let's watch the next step.
  Take the metal rod and hold it by the long end, like this.

- Take one long wire and hold one end of it against the long end of the rod, like this.

- Tilt the rod toward you, then wind the wire around this spoke.

- Let's use this large model to get a better view of how the wire is wrapped around the spoke.

  The wire goes over the top of the spoke, in this direction.

- Keep winding the wire carefully, and tightly back and forth, like this, until the spoke is covered.

- Keep winding until about one inch of the wire is left sticking out toward the long end of the rod, like this.

- Also, when you finish, the wire around the spoke should be tight like this and it should cover the spoke evenly all the way across.

- As you can see on this real turning part, when you are done, there are two wires about the same length sticking out from the spoke.

- Now let's wind the second spoke. Hold the metal rod by the long end again, like this.

- Take another long wire and hold one end against the long end of the rod.

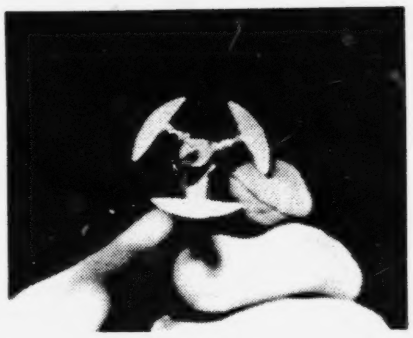
- Tilt the rod toward you and wind the wire around another spoke.

- Let's use the model again to see how the wire is wrapped around this spoke.

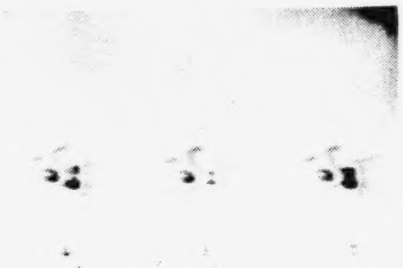
  The wire must also go over the top of this spoke like it did on the first spoke.

- Wind the wire carefully and tightly around the spoke.

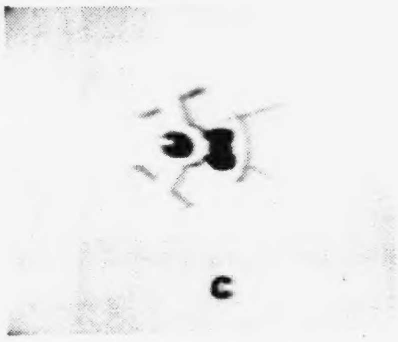
- Keep winding until about one inch of wire is left sticking out toward the long end of the rod, like this.



- When you finish, the wire on the second spoke should be tight and it should cover the spoke evenly all the way across.
- As you can see on this real turning part, you should also have two wires of about the same length sticking out from the second spoke.

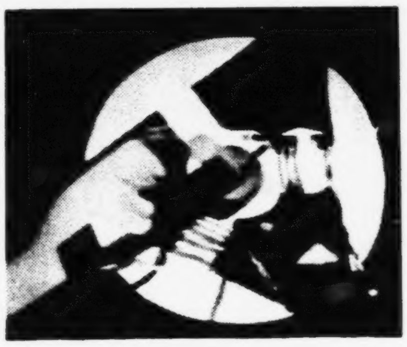


- Turn to page A-3 in your workbook. Put an X below the picture that shows the spoke with the wire correctly wrapped around it.



- You should have put an X below picture C.
- Turn to page A-4 in your workbook for another problem.

  Now look at the screen for a problem on how the wire should be wound.



- Here is choice A.

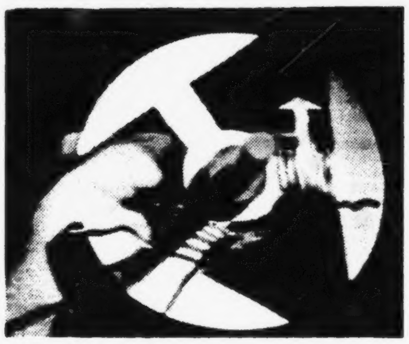
  The wire on one spoke should be wound over the top. The wire on the second spoke should also be wound over the top.

  If this is correct, put an X next to answer A.

- Here is choice B.

  The wire on one spoke should be wound over the top. The wire on the second spoke should be wound under the spoke.

  If this is correct, put an X next to answer B.



- You should have put an X next to answer A.

  The wire must go over the top of both spokes.

- Once again, hold the rod by the long end like this.

- Take the last long wire and hold it against the long end of the rod like this.

  Tilt the rod toward you and begin to wind the wire.

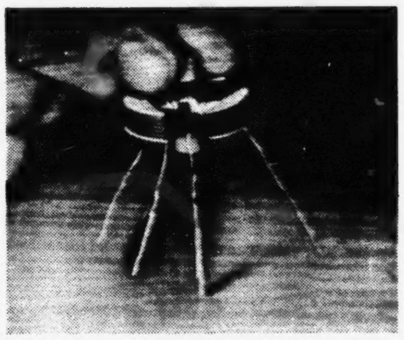
- Once again, let's use the model to see how the wire is wrapped around the empty spoke.

  Wind the wire over the top of the spoke, as you did on the first two spokes.

- Continue to wind the wire until about one inch is left sticking out toward the long end.

- When you finish, the third spoke should look like the other two. The wire should be tight and it should cover the spoke evenly all the way across.

- As you can see on this real turning part, you should also have two wires of about the same length sticking out from the last spoke.



- As you can see, there are two wires sticking out between these two spokes.

  There are also two wires sticking out between these two spokes and there are two wires sticking out between these two spokes.

- Take the two wires between these two spokes and twist them together like this.
  When you finish, you should have one wire.

- Now take the two wires from between two other spokes, twist them together, and make one wire like this.

- Turn to page A-5 in your workbook. Put an X below the picture that shows which two wires should be twisted together.

- You should have put an X below picture B.
- Let's continue putting the turning part together.
  Twist together the two wires left between the last two spokes and make one wire like this.
- Take the three wires you have just made and press them in toward the long end of the rod so that it looks like this.

- When you finish, the turning part should look like this.

- Turn to page A-6 in your workbook.
  Put an X below the picture that shows what the assembled turning part should look like.

- You should have put an X below picture B.

ARMATURE ASSEMBLY REVIEW

- Let's review how to assemble the turning part of the motor.

- Here are the small pieces that make up the turning part.

- First, straighten the three long wires.

- With a piece of sandpaper, scrape about one inch of the coating from each end of the three wires, until the wires look shiny like this.

- Put one large wheel on each side of the metal rod.

- Then, put one small tube against the large wheel on each side of the rod.

- Hold one long wire against the long end of the rod.

- Wind the wire evenly over the top of one spoke.

- When you finish winding, you should have two wires of about the same length sticking out from the spoke. The wire on the spoke should be tight and it should cover the spoke evenly all the way across.

- Then wind the last two wires in the same way over the top of the two other spokes.

- When you finish, you should have six wires sticking out from the spokes.

  All three wires should be wound tightly and evenly around the spokes.

- There should now be two wires between these two spokes, between these two spokes, and between these two spokes.

- Twist together the two wires from between two spokes and make one wire.

- Twist together the two wires from between these two spokes and make one wire.

- Twist together the two remaining wires and make one wire.

- Press the three wires you have made toward the long end of the rod.

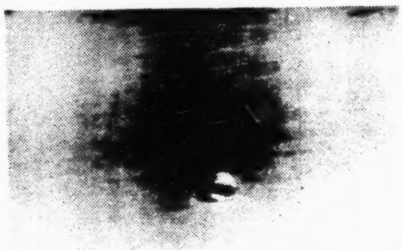
- The assembled turning part should look like this.

COMMUTATOR ASSEMBLY

- Another major part inside this motor is a plastic tube.

- This is what the plastic tube looks like when it is taken off the turning part.
- Before we can put this plastic tube together, we have to be able to recognize all the small parts that make it up.
- There is a plastic cap with a hole in it on this end.

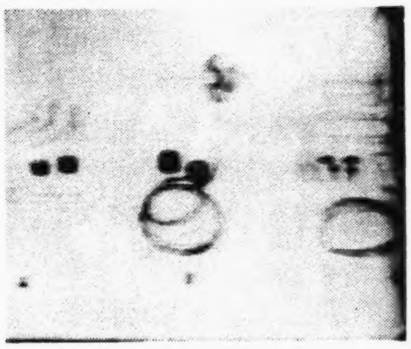
- This is what the cap looks like when it is not put on the plastic tube.
- There is a plastic ring on the tube.



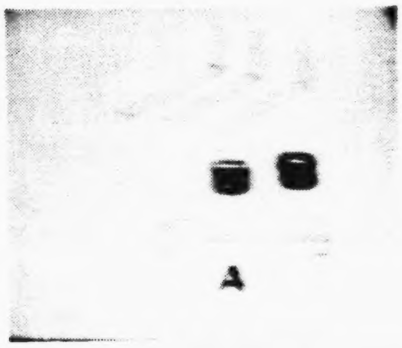
- This is what the ring looks like when it is not on the plastic tube.
- There are three "L" shaped strips of copper around the tube.

- This is what the three "L" shaped strips look like when they are not assembled.

- And there is a long plastic tube with ridges on it like this.
- Let's see if you can pick out the small parts that make up this plastic tube.

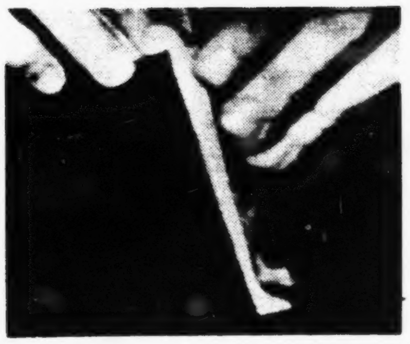


- Turn to page B-1 in your workbook. Put an X below the picture that shows the small pieces that make up the plastic tube.



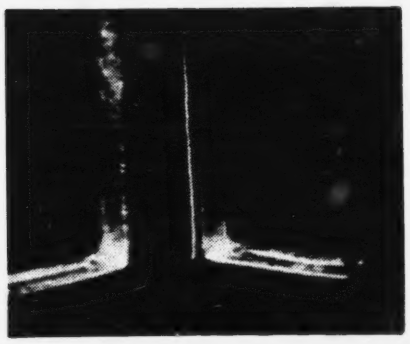
- You should have put an X below picture A.

- Because the tube is so small, let's use this model to get a better view.
- The plastic tube has ridges that run the length of the tube, here and here and here. They are painted black to give you a better view.

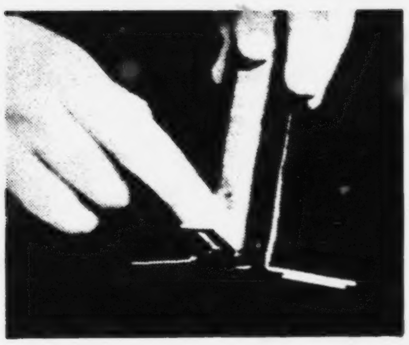


- The first thing to do is to put one of the "L" shaped copper strips in the space between two of the ridges, like this.

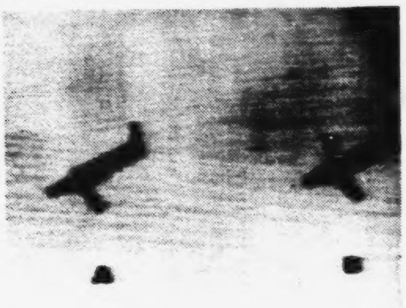
- Put the second copper strip in another space.
- The two pieces of copper must be separated all the way down by a ridge.
- Put the third copper strip in the last space.



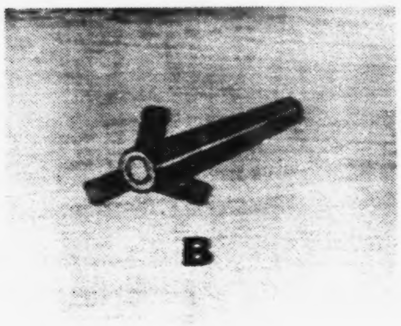
- Ridges must separate all the strips of copper.



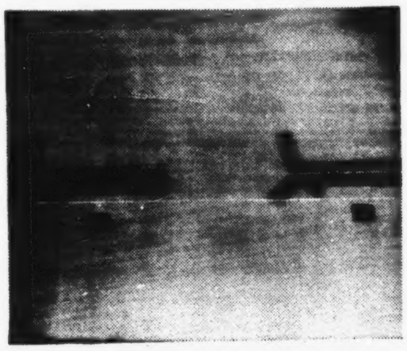
- The bent over pieces must all be at this end of the plastic tube.



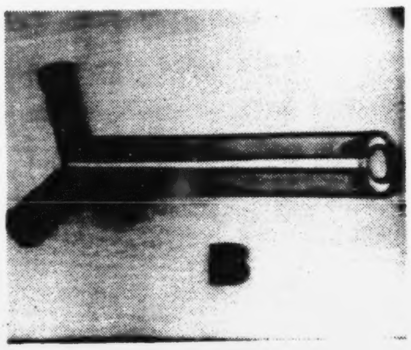
- Turn to page B-2 in your workbook. Put an X below the picture that shows how the "L" shaped copper strips should be placed around the plastic tube.



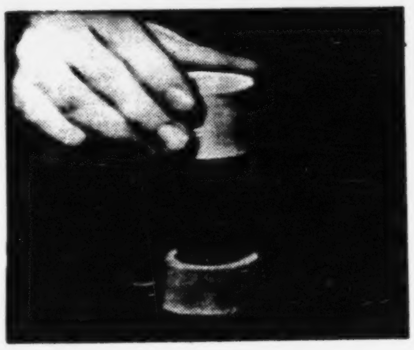
- You should have put an X below picture B.



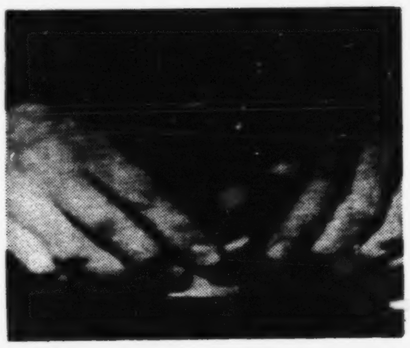
- Turn to page B-3 in your workbook. Put an X below the picture that shows how the "L" shaped strips of copper should be placed on the plastic tube.



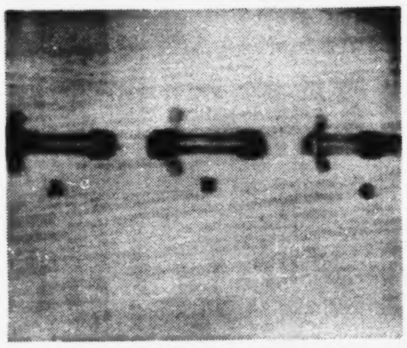
- You should have put an X below picture B.
- Let's continue putting the plastic tube together. Take the plastic ring.
- Slip the ring onto the tube, like this.



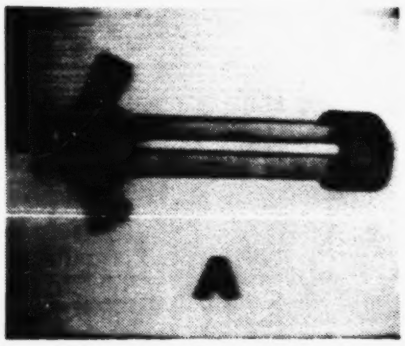
- Push the ring all the way down to the end of the tube. The ring is right against the bottom part of the "L", here.
- Finally, take the cap with a hole in it.



- Push the cap onto this end of the tube making sure that the cap goes over the copper strips.
- When you finish, the real plastic tube should look like this.



- Turn to page B-4 in your booklet. Put an X below the picture that shows the way the ring and cap should be assembled.



- You should have put an X below picture A.

COMMUTATOR REVIEW

- Let's review how to assemble the plastic tube part of the motor.

- Here are the small pieces that make up the tube part.

- Put the three "L" shaped strips of copper in the spaces between the ridges on the long plastic tube.

  Be sure that the "L" shaped strips of copper do not touch each other.

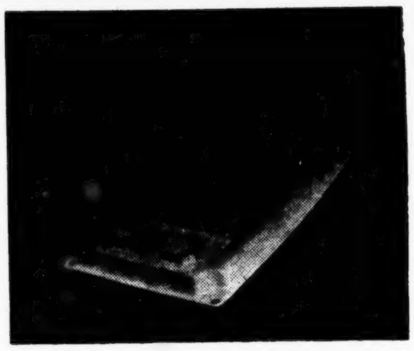
- Next slip the ring onto the tube. Push the ring all the way down to the end of the tube next to the bottom part of the "L."

- Then put the cap with a hole in it onto the end of the tube.
  Make sure that the cap goes over the copper strips.

- When the plastic tube is completely assembled, it should look like this.

BASE ASSEMBLY

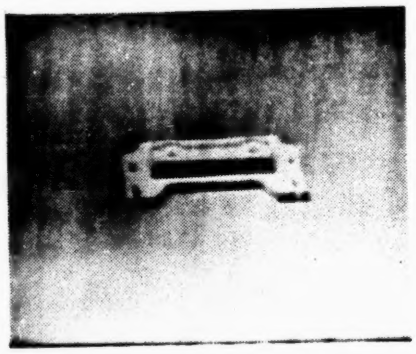
- The third major part inside this motor is the base.



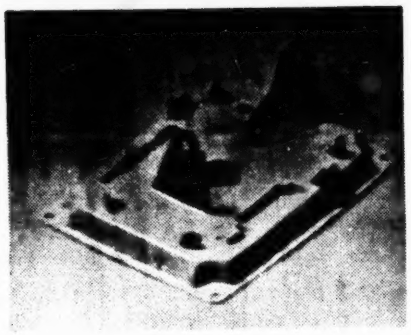
- This is what the base looks like when it is taken out of the motor.
- Before you can put the base together, you have to be able to recognize all the small parts that make it up.
- There are two bent pieces of copper, one here and one here.

- This is what the two bent pieces of copper look like when they are not assembled.
- There are two tiny screws and two tiny washers that hold the bent pieces of copper in place.

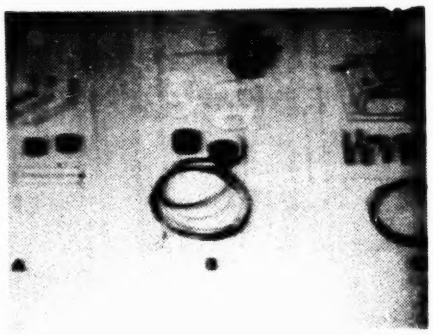
  There is a screw and washer here and a screw and washer here.
- This is what the screws and washers look like when they are not assembled.
- There is a small plastic platform mounted on the base.



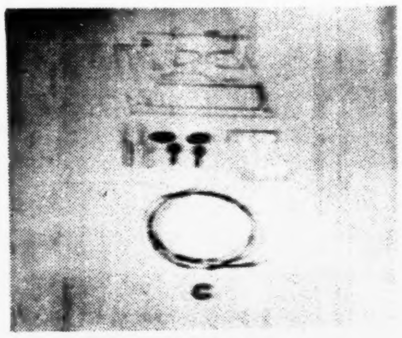
- This is what the plastic platform looks like when it is not mounted on the base.



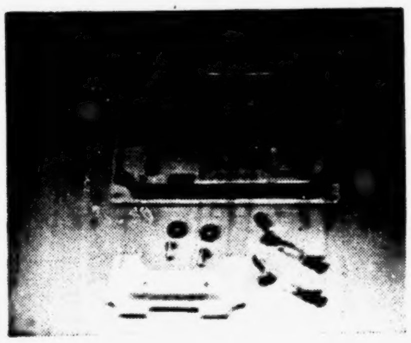
- Finally there is the base itself.



- Let's see if you can pick out the small parts that make up the base of the motor. Turn to page C-1 in your workbook. Put an X below the picture that shows all the small pieces that make up the base.



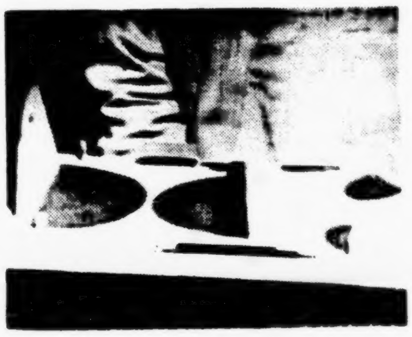
- You should have put an X below picture C.



- Now, let's see how these parts are put together.
- The first thing to do is to attach the platform to the base.
- The platform goes on at this end of the base. This end of the base has two upright pieces of metal that fit on the outside of the platform. One here and one here.

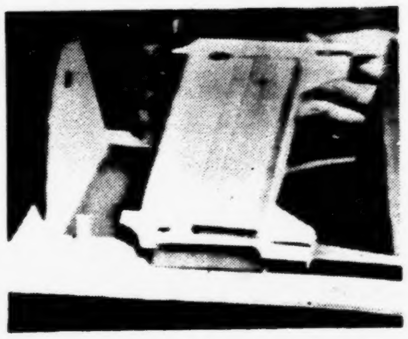
- In addition to the outside pieces of metal, this end also has two upright pieces of metal that fit through these two holes in the platform.

- And this end of the base has one big upright piece that fits in this groove of the platform.

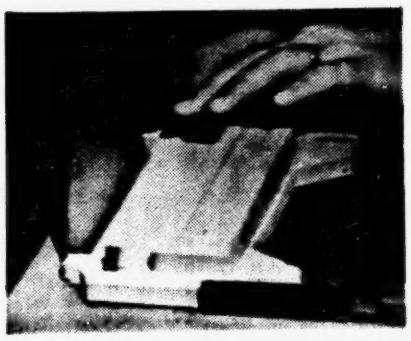


- Let's use this model to get a better view. That is what the base looks like when nothing is attached to it.

- The end of the base where the platform goes has these two upright pieces, these two upright pieces and this large upright piece.

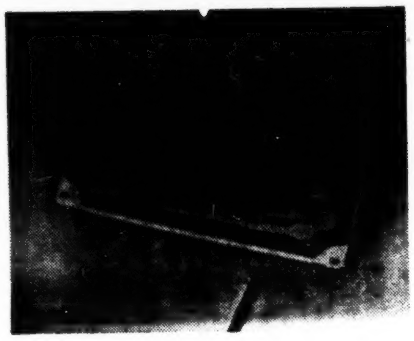


- Put the platform on the base, so that these upright pieces of metal in the base fit through these two holes in the platform. The big upright piece of metal should fit in this groove. These two pieces of metal are on the outside of the platform holding it in place.



- Now take the screwdriver and bend the pieces of metal that slide through these holes so that they hold down the platform.

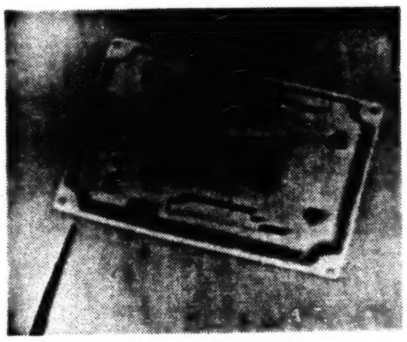
- This is what the real base looks like when the platform is put on.



- Turn to page C-2 in your workbook. Look at the screen for the problem.

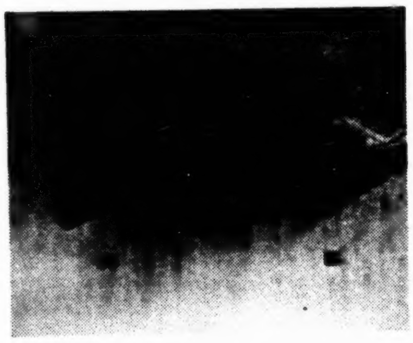
  Should the platform go on this end of the base or should it go on this end of the base?

  Put an X in your workbook below the end of the base on which the platform should go.

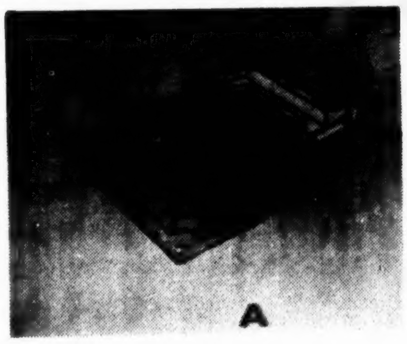


- You should have put an X below this end of the base.

  This is what it should look like when the platform is put on.



- Turn to page C-3 in your workbook. Put an X below the picture that shows which way the platform should be put on the base.

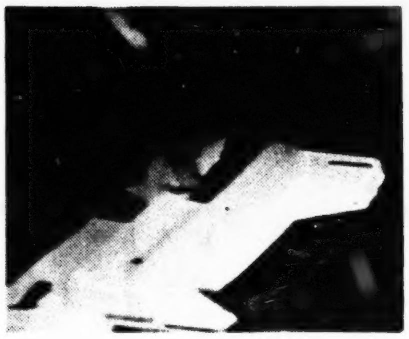


- You should have put an X below picture A.

- Now, take one screw and put it through the center of one of the washers, like this.

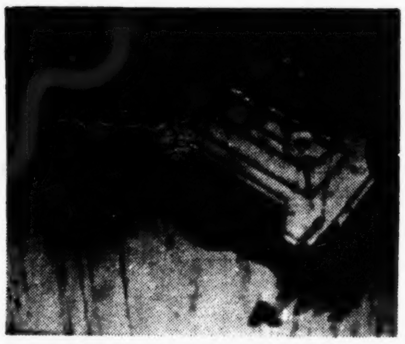
- Then, take one of the bent pieces of copper and put the screw through the big hole, in the middle.

- Put the screw into one of the round holes on the platform.



- As you can see, the long end of the bent piece of copper is toward the center of the platform, here. And the short end with a hole in it is toward the outside of the platform.
- Take the screwdriver and turn the screw a few times. But do not tighten the screw completely.

- Turn to page C-4 in your workbook. Put an X below the picture that shows where the long part of the piece of copper should be.



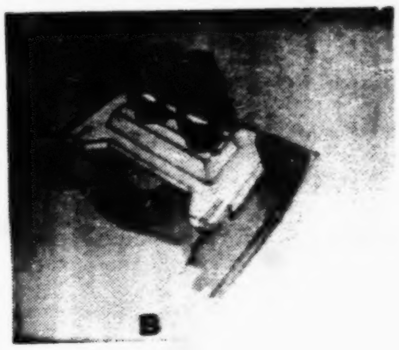
- You should have put an X below picture A.
- Now, take the other screw and washer,
- and put them through the big hole in the middle of the other bent piece of copper.
- Put the screw in the other round hole in the platform.
- Turn the screw a few times with the screwdriver. But do not tighten the screw completely.

Once again, the long side is toward the center of the platform.

- Both long parts should be toward the center of the platform and both short parts should be toward the outside of the platform.

- This is what the base looks like when it is correctly assembled.

- Turn to page C-5 in your workbook. Put an X below the picture that shows how the bent pieces of copper should be put on the platform.



B

- You should have put an X below picture B.

BASE ASSEMBLY REVIEW

- Let's review how to assemble the base of the motor.

- Here are the small parts that make up the base.

- First, attach the platform to the base, and bend the upright metal pieces that go through the holes in the platform to keep it in place.

- Next, put a screw through one of the washers. Then, put the screw through the big hole in the center of the bent piece of copper.

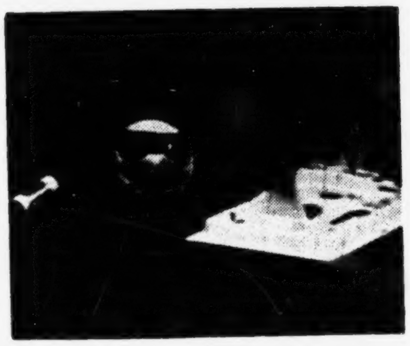
- Put the screw into one of the holes in the platform. Turn the screw a few times, but do not tighten it completely. The long part of the piece of copper should face toward the center.

- Do the same thing on the other side.

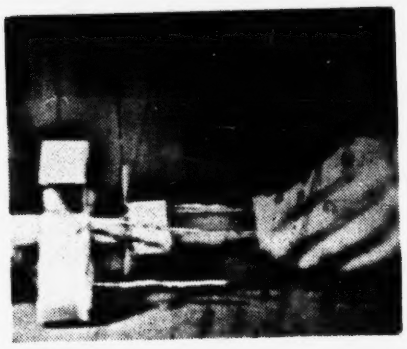
- When the base is correctly assembled, it should look like this. Both long ends of the pieces of copper should be facing the center.

CONNECTING THE MOTOR PARTS

- There are three major parts to this motor.
- There is a plastic tube. This is what the plastic tube looks like when it is taken out of the motor.
- There is a turning part. This is what the turning part look like when it is taken out of the motor.
- And there is the base. This is what the base looks like when the plastic tube and the turning part are not attached to it.

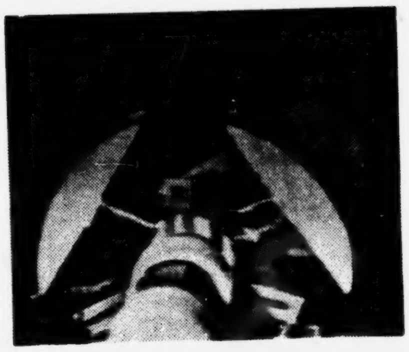


- Now, let's see how these parts are put together.
- Let's use the model to get a better view of the next step.
- Take the turning part and the plastic tube. They are assembled first.



- With the "L" shaped copper strips facing toward the long end of the metal rod, slide the plastic tube onto the long end of the metal rod. The "L" shaped strips should touch this small tube.

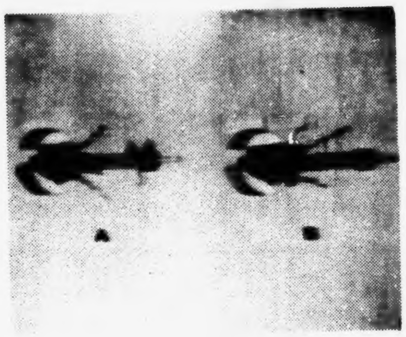
- Rotate the tube so that the ends of the "L" shaped copper strips are between the spokes of the turning part.



- There should be a strip of copper between these two spokes, between these two spokes, and between these two spokes.

- Take the twisted wire between two poles and wrap the shiny ends around the tip of the "L" shaped piece of copper that is between the same two spokes. Be sure to wrap the wire tightly.

- Take hold of the second twisted wire between two other spokes and wrap it tightly around the copper strip that is between the same two spokes.



- Turn to page D-1 in your booklet. Put an X below the picture that shows the turning part and tube correctly assembled.

- You should have put an X below picture B. This is what the real parts look like when the tube and the turning part are correctly put together.

- Using the model, let's continue putting the parts of the motor together.

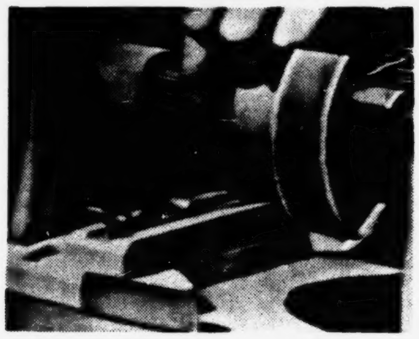
  Take the last twisted wire and wrap it tightly around the third metal strip.

- Now, let's attach this part of the motor to the base.

- Put the end of the turning part with the tube on it between the bent pieces of copper and through the hole in this upright piece of metal.

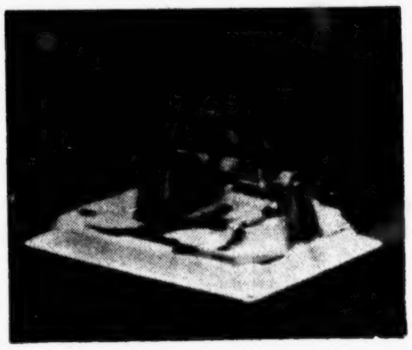
- Bend this upright piece of metal back a little bit and put the short end of the rod through the hole in it.

- The turning part and tube should turn easily when they are put on the base.



- Slide one of the copper pieces that are attached to the platform toward the center of the platform as far as it will go. It should touch the tube. Hold it there. With the screwdriver, tighten the screw all the way.

- On the other side, slide the bent piece of copper toward the center, as far as it will go and hold it there. This copper strip should also touch the tube. Now tighten the screw.



- When you finish, this is what the real parts of the motor should look like. Both pieces of copper should be touching the plastic tube.

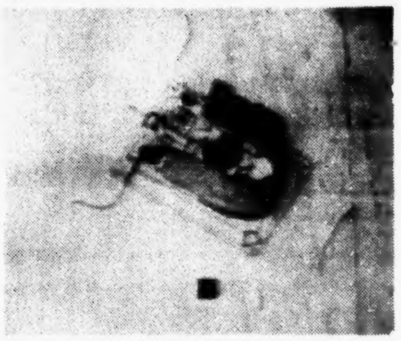
- Turn to page D-2 in your workbook. Put an X below the picture that shows where the two bent pieces of copper should be.

- You should have put an X below picture A.
- To complete the motor, you have to attach a magnet here.
- This is what the magnet looks like when it is not attached.

- The edges of the magnet fit into the slits here and here on the platform.

  With your fingers, squeeze the sides of the magnet together and slide the edges of the magnet into the slits. When the magnet is correctly in place, these metal strips in back of the magnet will hold it firmly.

- Turn to page D-3 in your workbook. Put an X below the picture that shows the magnet correctly put on the base.



- You should have put an X below picture B.

  Both edges of the magnet fit into the slits on the platform, like this.

- Next, with a small piece of sandpaper, scrape the coating from both ends of each of these short wires.

- When you finish, about one inch of each end of the wires should be shiny.

- One end of the wire goes through this hole in the bent piece of copper.

  Take one short wire and slip it through the hole.

  Wrap the wire tightly around the bent piece of copper, a few times.

- Take the other short wire and put it through the hole in the other bent piece of copper. Wrap it around the bent piece of copper, a few times.

- The next step is to attach the wires from the motor to the battery holder.

  Put one of the wires through the hole in one of the upright pieces of metal.

  Wrap the wire tightly around the upright piece of metal.

- Put the other wire through the hole in the other upright piece of metal. Wrap the wire tightly around it.

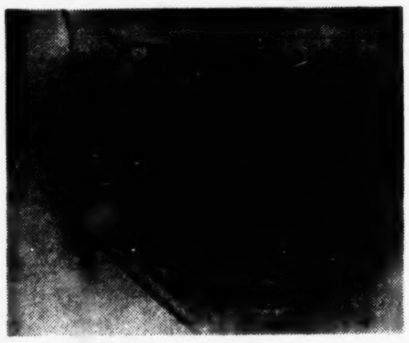
  The assembled motor should look like this.

- To start the motor, put the battery in the battery holder.

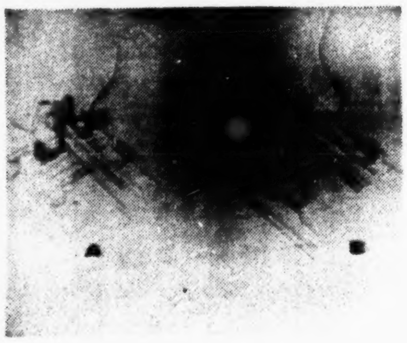
  The ends of the battery should be touching the battery holder here and here.

  To stop the motor, remove the battery from the battery holder.

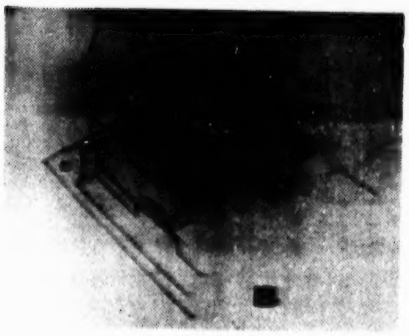
- Turn to page D-4 in your workbook. Put an X below the picture that shows which ends of the bent pieces of copper the wires should be attached to.



- You should have put an X below picture B. The wires should be attached to the ends that have the holes in them.



- Turn to page D-5 in your workbook. Put an X below the picture that shows how the wire should be attached to the bent pieces of copper.



- You should have put an X below picture B. The wires should be wrapped tightly.

CONNECTING THE MOTOR PARTS REVIEW

- Let's review how the three major parts of the motor are assembled and the entire motor is completed.
- First, slide the plastic tube onto the turning part, until the ends of the "L" shaped copper strips touch the small tube. Each copper strip is between two spokes.
- Wrap the twisted wire between two spokes around the "L" shaped strip of copper that is between the same two spokes.

  Do this with all three twisted wires.
- Put the assembled part onto the base with the tube between these upright copper strips.
- Slide one of the bent pieces of copper toward the center of the platform until it touches the tube. Then tighten the screw.
- Do the same thing on the other side.
- Be sure that both bent pieces of copper are touching the plastic tube.
- Squeeze the sides of the magnet and slide the magnet into the slits on the platform.

- Then sandpaper the ends of the wires. Be sure that about one inch of each end of the wires is shiny, like this.
- Put the wires through the holes in the bent pieces of copper, and wrap the wires tightly around the bent pieces of copper.
- Attach the wires to the battery holder. To start the motor, put the battery in the batter holder.

APPENDIX B

PROGRAMMING PROCEDURAL LEARNING

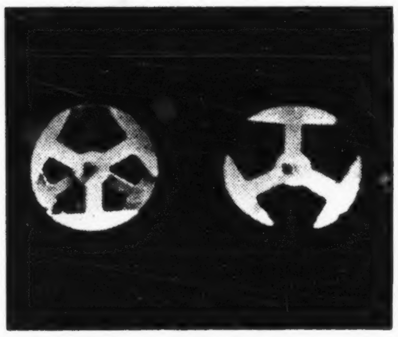
Editing Items for Assembling a Motor

Page

A. Armature B-1
B. Commutator B-6
C. Base B-8
D. Connecting Motor Parts B-10

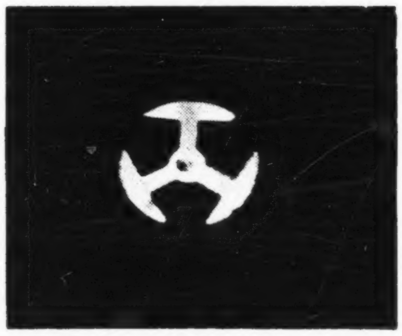
EDITING ITEMS FOR ARMATURE

- In learning how to do something, it is always important to get some practice.

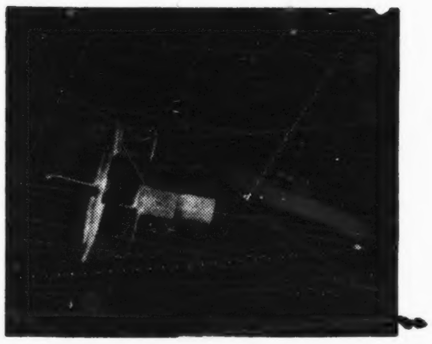


- Which of these turning parts has the wheel put on correctly?

  Turn to page E-1 in your workbook. Put an X below the picture that shows the wheel in the correct position.



- You should have put an X below picture B. The wheels and the spokes should be lined up.



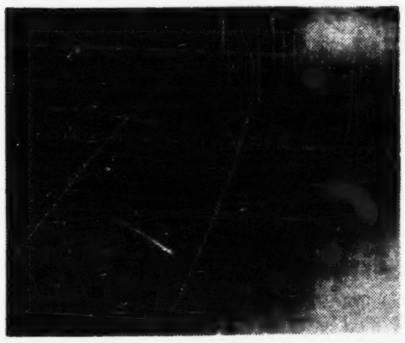
- Is this turning part correctly assembled?

  Turn to page E-2 in your workbook. Answer the question on that page.

  If your answer is no, circle the part in the picture that is in the wrong place.

- You should have marked no and circled this tube.

  This tube should go on the other side, like this.

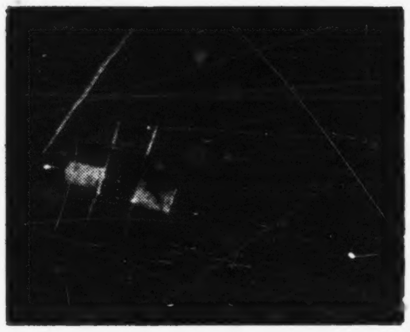


- Look at these wires. Are they ready to be put on the turning part?

  Turn to page E-3. Put an X beside all the wires that are ready to be put on the turning part.

- You should have put an X beside the top wire and beside the bottom wire.

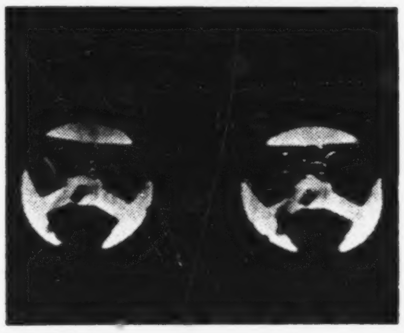
  The end of the middle wire needs to be scraped with sandpaper and made shiny.



- When you start to wind the wire, you hold the wire against one end of the metal rod.

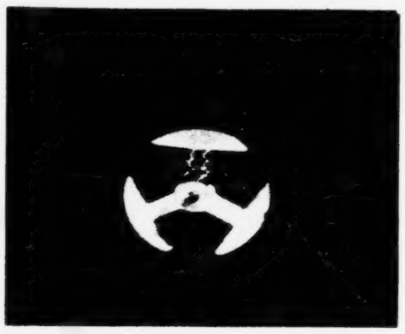
  Turn to page E-4. Do you hold the wire against this end or this end? Put an X below the end that you hold the wire against.

- You should have put an X below the long end of the rod.



- Turn to page E-5.

  Which spoke is correctly wound? Put an X below it.

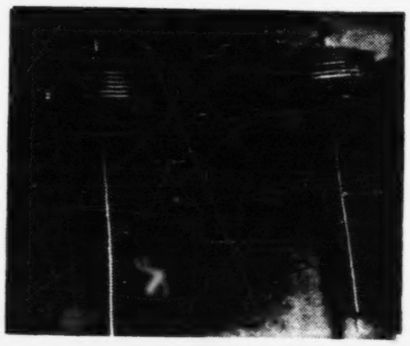


- You should have put an X below picture A. The wire is wound tightly and spreads evenly all the way across.

- Watch how the wire is being wound. Is it being done correctly to both spokes? The wire goes over the top on one spoke. The wire goes under the bottom on the next spoke.

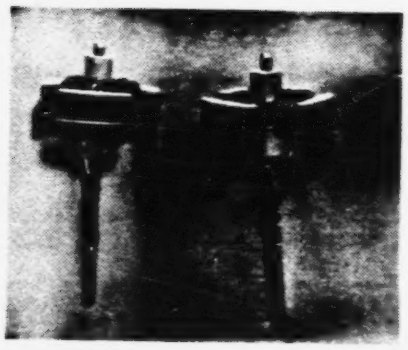
  Turn to page E-6. Check whether the wires were correctly wound. If one wire goes over the top on one spoke, should the wire on the second spoke go under the bottom?

- You should have checked no. Both wires should have gone over the top.



- When you finish winding, part of the wire should be sticking out. Which one of these turning parts has the right amount of wire sticking out?

  Turn to page E-7. Put an X below the picture that shows the right amount of wire sticking out.



- You should have put an X below picture B. Both wires should be sticking out the same amount, about one inch.

- After the wires are wound, you must twist them together.

  Turn to page E-8. Put an X below the picture that shows which two wires should be twisted together.

- You should have put an X below picture B. As you can see on the screen, the two wires from between two spokes should be twisted together.

- Are the correct wires twisted together here?

  Turn to page E-9. Answer the question on the page.

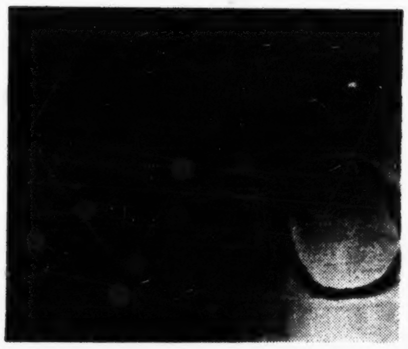
- You should have answered yes. You should twist the wires from between two spokes.

- Which two wires should be twisted together?

  Turn to page E-10. Put an X below the two wires that should be twisted together.

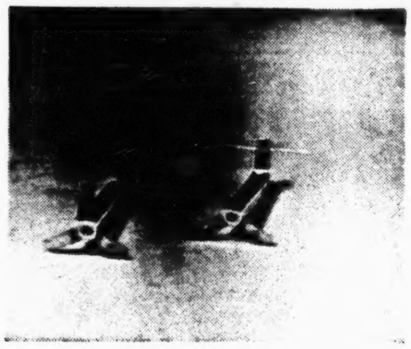
- You should have put an X below wire B and wire C.

  These two wires between two spokes should be twisted together.



- Turn to page E-12.

  Put a circle around all the small parts that make up the turning part. You will have half a minute.



- Look at the screen.

  You should have circled all these parts.

EDITING ITEMS FOR COMMUTATOR

- Which of these tubes has the metal strips put on correctly?

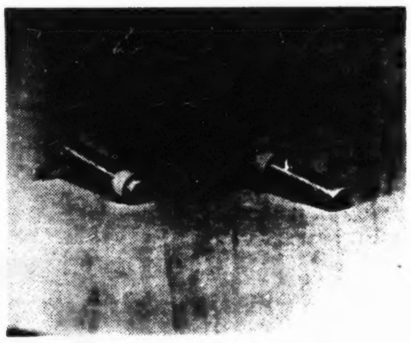
  Turn to page F-1 in your workbook. Put an X below the picture that shows the metal strips put on the tube correctly.

- You should have put an X below picture A. The bent parts should all be at the same end.

- Are the metal strips correctly placed around this tube?

  Turn to page F-2 in your workbook. Answer the question on that page. If your answer is no, write down what you would do to correct the problem.

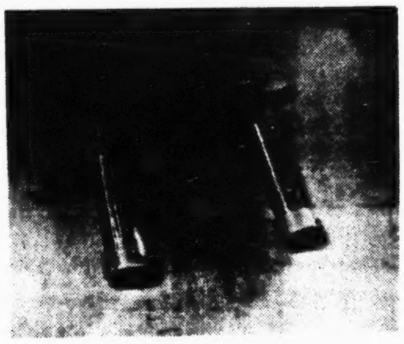
- You should have marked no and said that you would separate the metal strips so that they don't touch.



- Which of these two tubes has the plastic ring correctly put on?

  Turn to page F-3. Put an X below the picture that has the plastic ring put on correctly.

- You should have put an X below picture B. The plastic ring goes right against the bent ends of the metal strips.



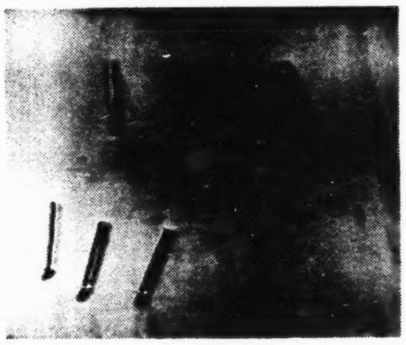
- Which of these two tubes has the plastic cap put on correctly?

  Turn to page F-4. Put an X below the picture that shows the plastic cap correctly put on the tube.

- You should have put an X below picture B.
  The plastic cap goes over all the metal strips.

- Turn to page F-5.

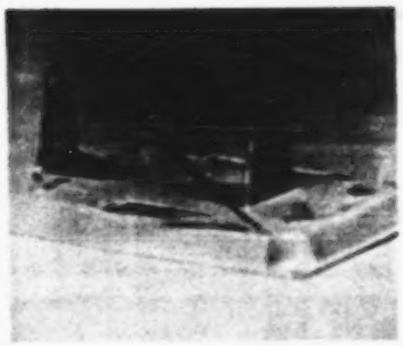
  Put a circle around all the small parts that make up the plastic tube.



- Look at the screen.

  You should have circled all these parts.

EDITING ITEMS FOR BASE

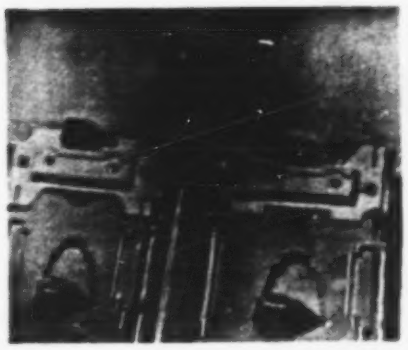


- On which end of the base does the platform go? Here or here?

  Turn to page G-1. Put an X below the end of the base where the platform should go.

- Look at the screen again.

  You should have put an X below this end of the base.



- Which of these two platforms is put on the base correctly?

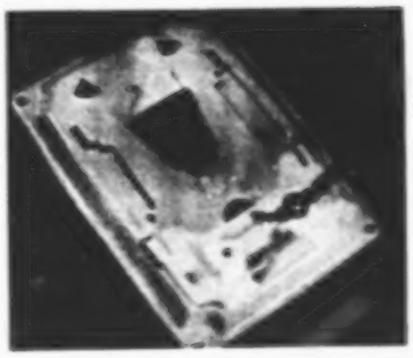
  Turn to page G-2. Which one of these two pictures shows the platform put on the base correctly?

- You should have put an X below picture A.

- Which of these is assembled correctly?

  Turn to page G-3. Put an X below the picture that shows the screw, washer and piece of copper assembled correctly.

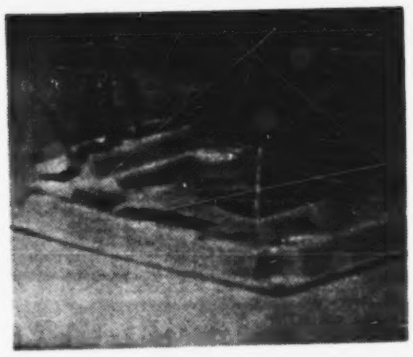
- You should have put an X below picture B.



- Is the piece of copper correctly attached to the platform?

  Turn to page G-4. Answer the question on that page.

- You should have marked yes.



- Are both pieces of copper put on the platform correctly?

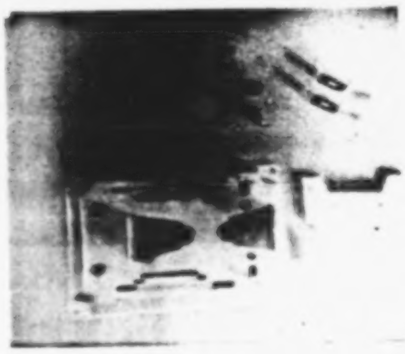
  Turn to page G-5. Answer the question on that page. If you answer no, circle the piece of copper that is put on incorrectly.

- You should have marked no and circled this piece of copper.

  The end with the hole in it should face toward the outside of the platform.

- Turn to page G-6.

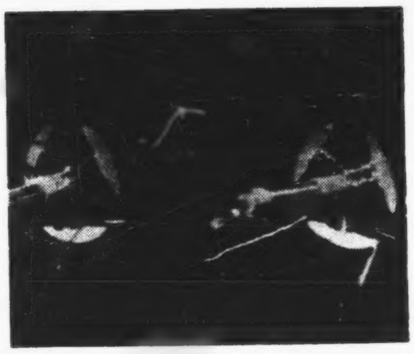
  Put a circle around all the parts that make up the base.



- Look at the screen.

  You should have circled all these parts.

EDITING ITEMS FOR CONNECTING MOTOR PARTS



- Which of these tube parts is put on the turning part correctly?

  Turn to page H-1 in your workbook. Put an X below the picture that shows the tube part put on the turning part correctly.

- You should have put an X below picture A. The "L" shaped ends go against the small tube on the turning part.

- Look at these "L" shaped pieces of copper. What position should they be in?

  Turn to page H-2 in your workbook. Put an X below the picture that shows what position the "L" shaped pieces of copper should be in.

- You should have put an X below picture B.

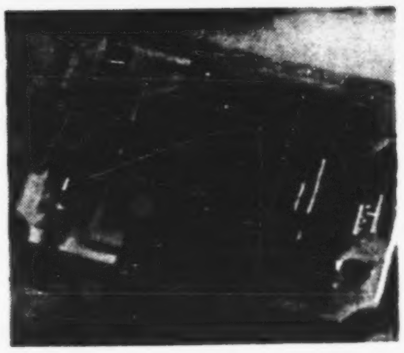
  The "L" shaped pieces of copper should go between the spokes on the turning part.

- Turn to page H-3 in your workbook.

  Circle the wire that should be twisted around the piece of copper marked A.

- The piece of copper marked A is between these two spokes.

  You should have circled the wire between the same spokes.

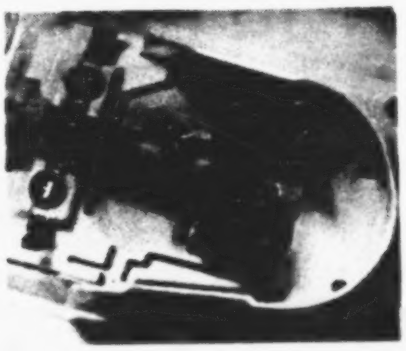


- Are the bent pieces of copper in the correct position?

  Turn to page H-4. Answer the question on that page.

  If you answer no, circle the part that is not assembled correctly.

- You should have marked no and put a circle around this piece of copper. Both pieces of copper should be touching the tube part.



- Is this magnet put on the base correctly?

  Turn to page H-5. Answer the question on that page.

- You should have marked no. Both edges of the magnet should fit into the slits in the platform.

- Is this wire ready to be attached to the copper strips on the platform?

  Turn to page H-6. Answer the question on that page.

  If your answer is no, write down what you would do to make it ready.

- You should have said no and said that you would sandpaper this end of the wire.

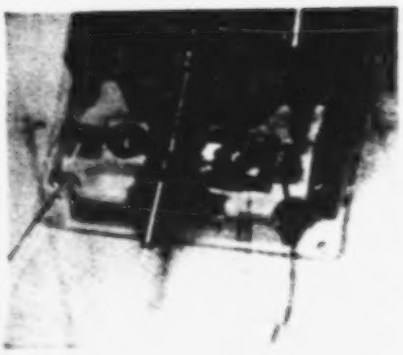
  About one inch at each end of the wires should be shiny.

- Which piece of copper has the wire correctly attached to it, this one or this one?

  Turn to page H-7. Put an X below the piece of copper that has the wire attached to it correctly.

- You should have put an X below this piece of copper.

  The wire is attached to the end with the hole in it.



- Turn to page H-8.

  Put an X below the piece of copper that shows the wire correctly wrapped around it.

- You should have put an X below this piece of copper.

  The wire should be wrapped tightly.

APPENDIX C

1. Workbook for response-practice during demonstration.

2. Workbook for recognition response-practice following demonstration.

A
TURNING PART

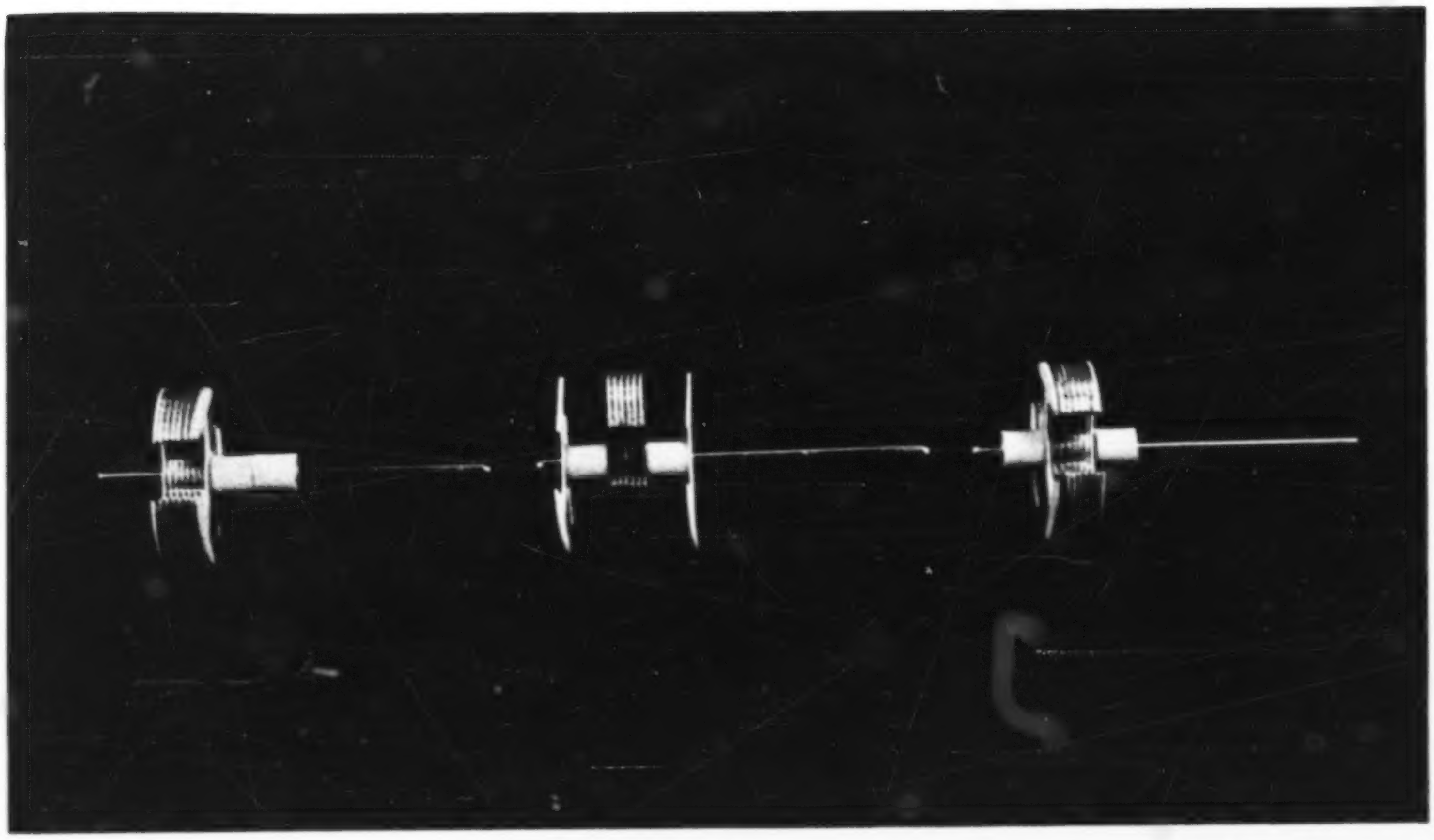
NAME____

DATE____________________ SEX____________________

LOCATION________________

CONDITION________________

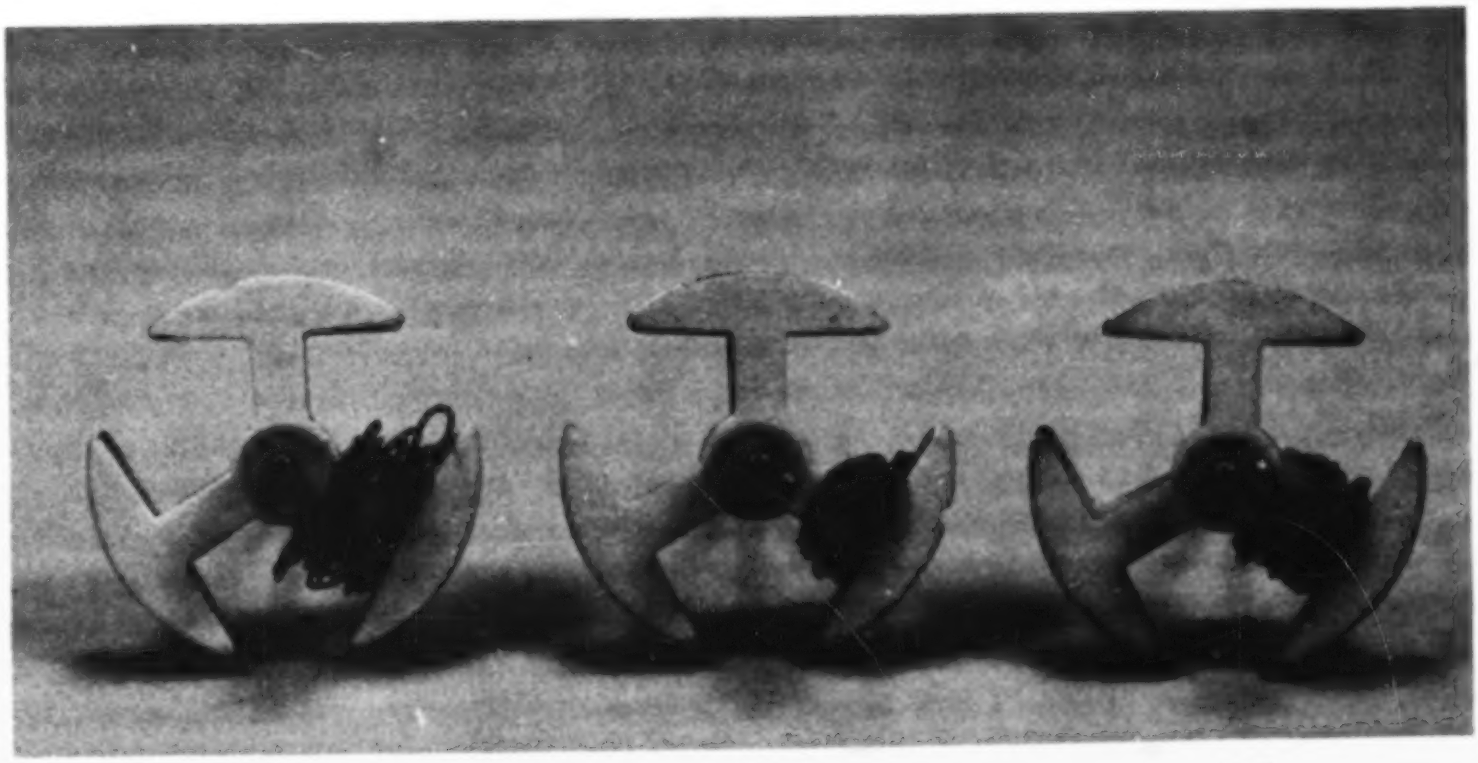
☐ A ☐ B ☐ C



☐ A

☐ B

☐ C



☐ A

☐ B

☐ C

A

Spoke number 1 -- over the top

Spoke number 2 -- over the top

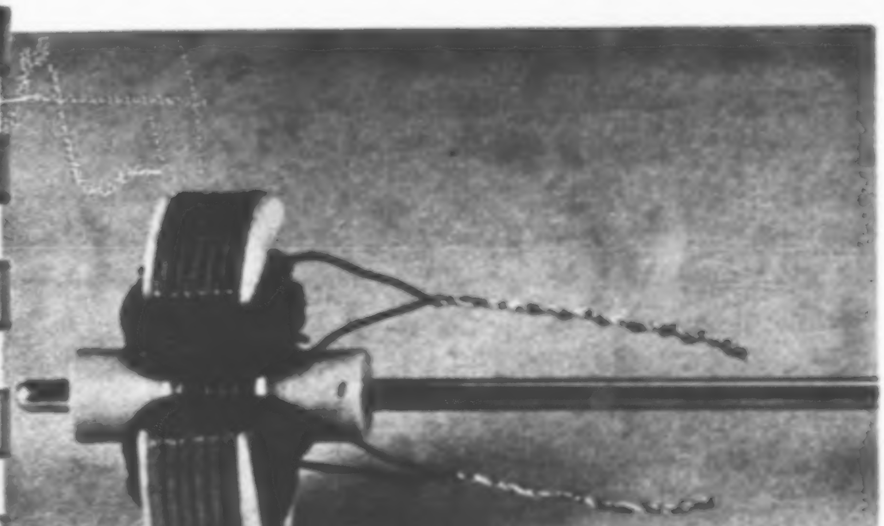
☐

B

Spoke number 1 -- over the top

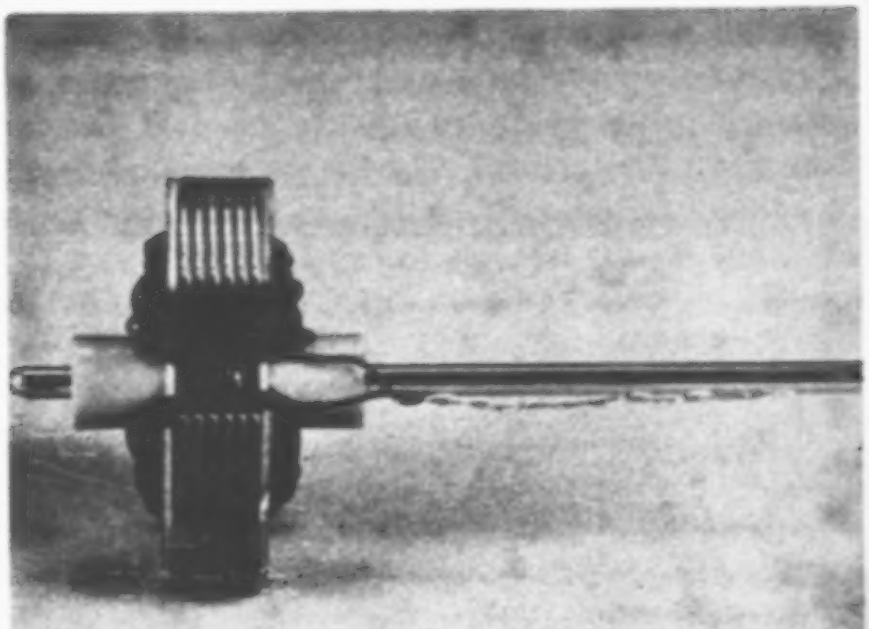
Spoke number 2 -- under the bottom

☐



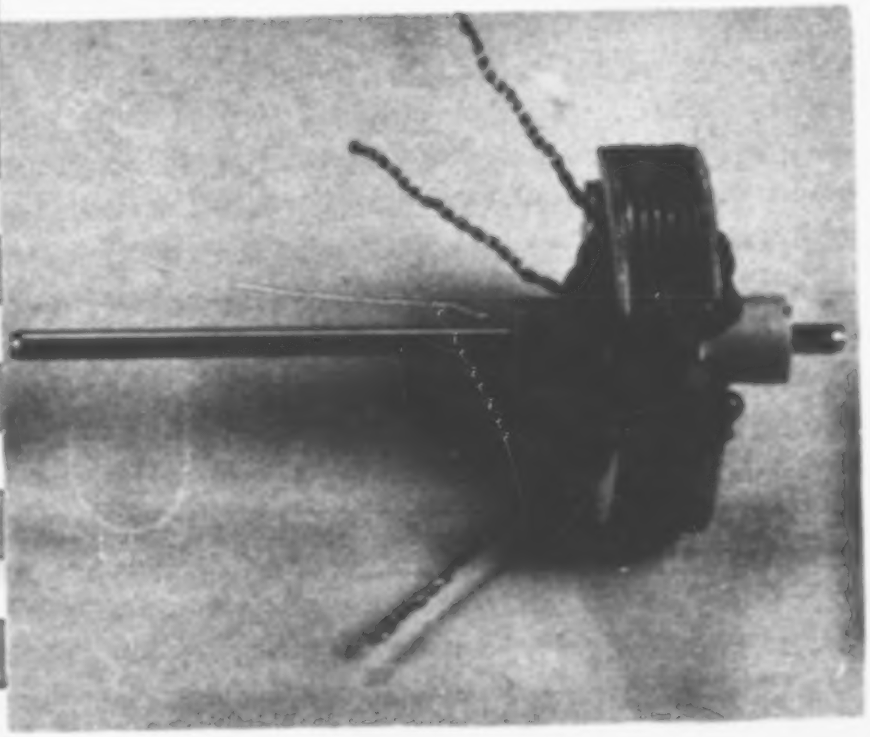
☐

A



☐

B



☐

A

☐

B

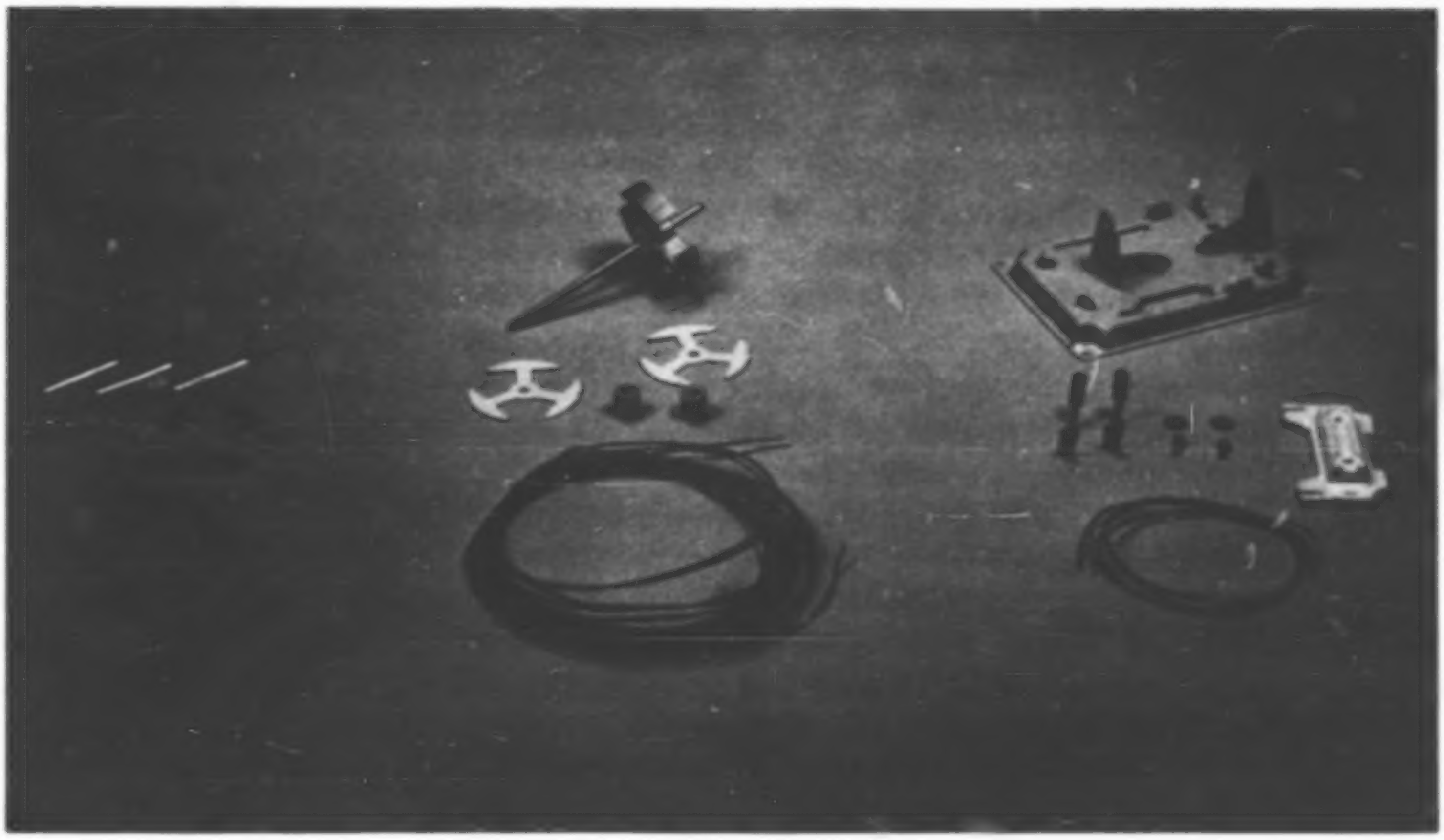
B
TUBE PART

NAME____

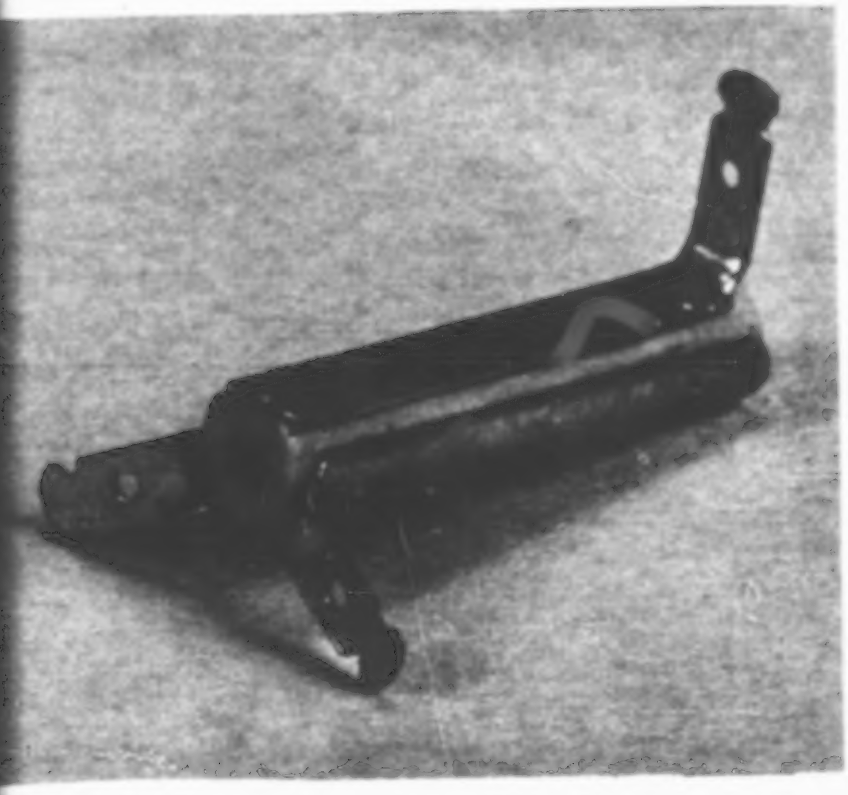
DATE__________________ SEX____________________

LOCATION________________

CONDITION_______________

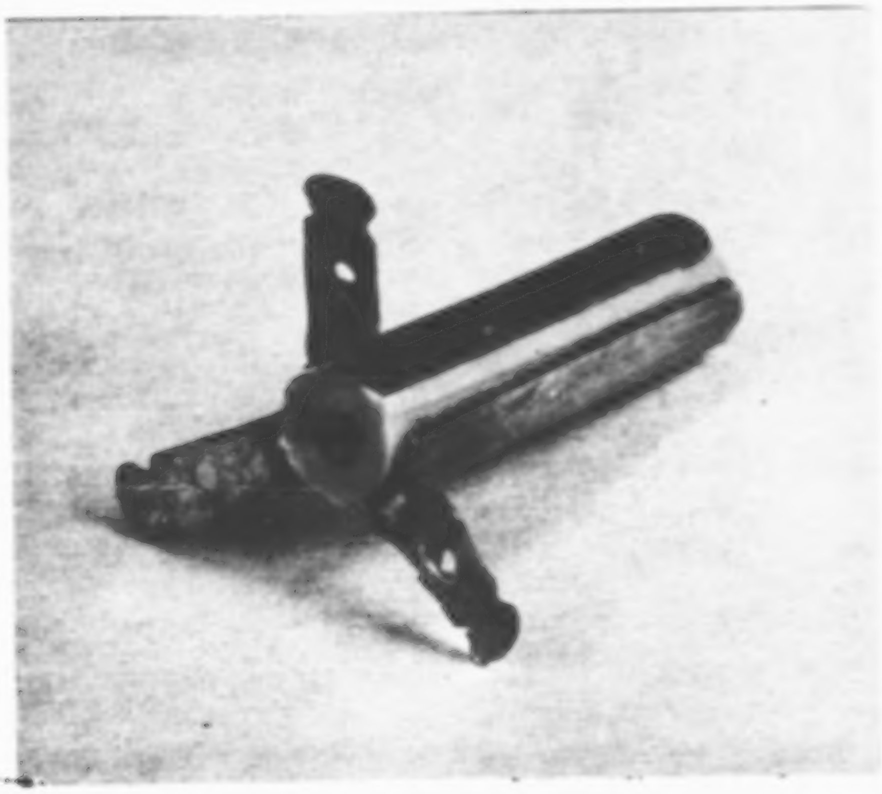


☐ A ☐ B ☐ C



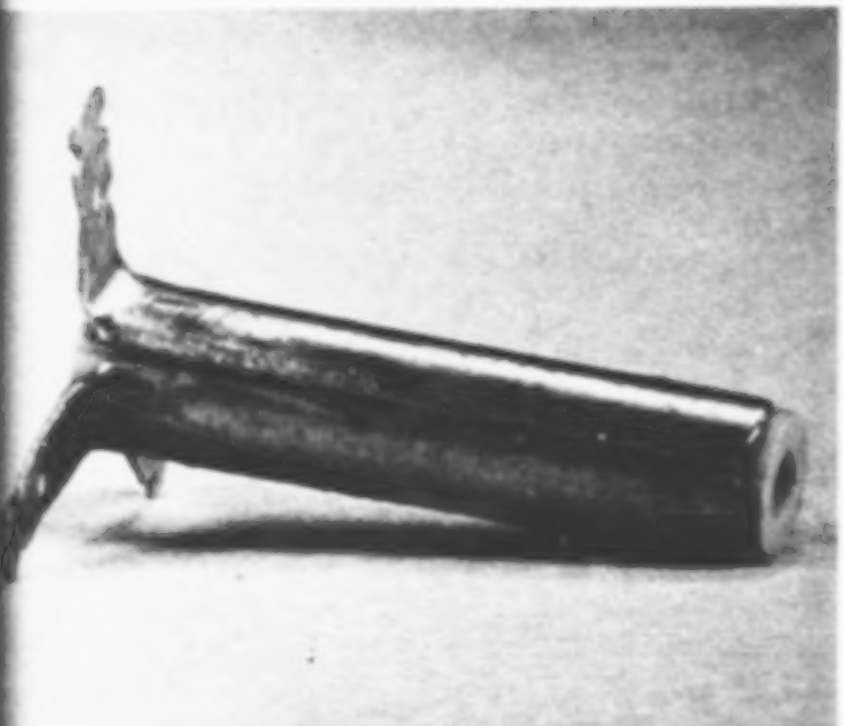
☐

A

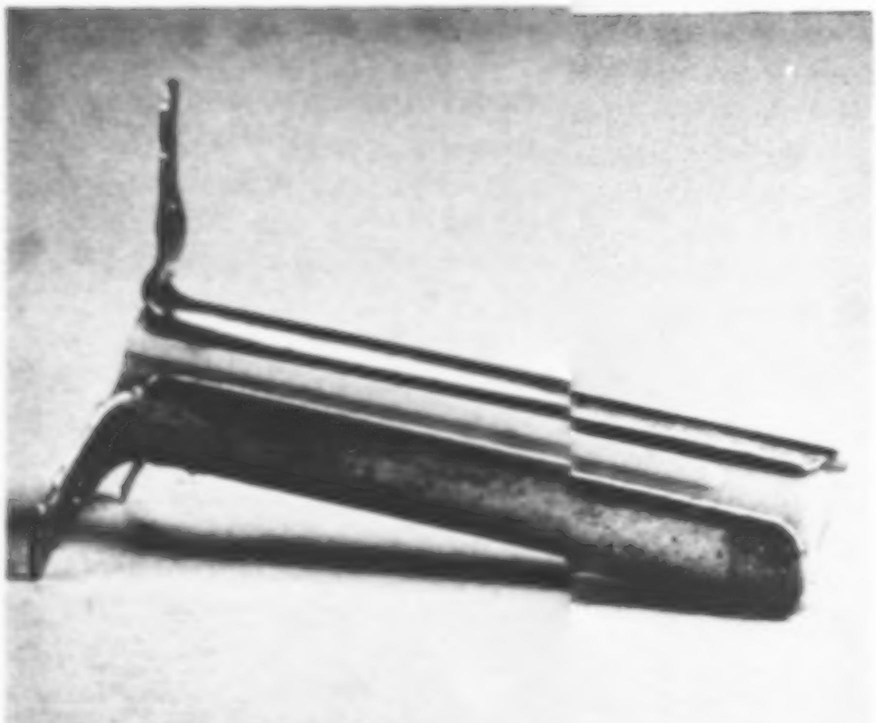


☐

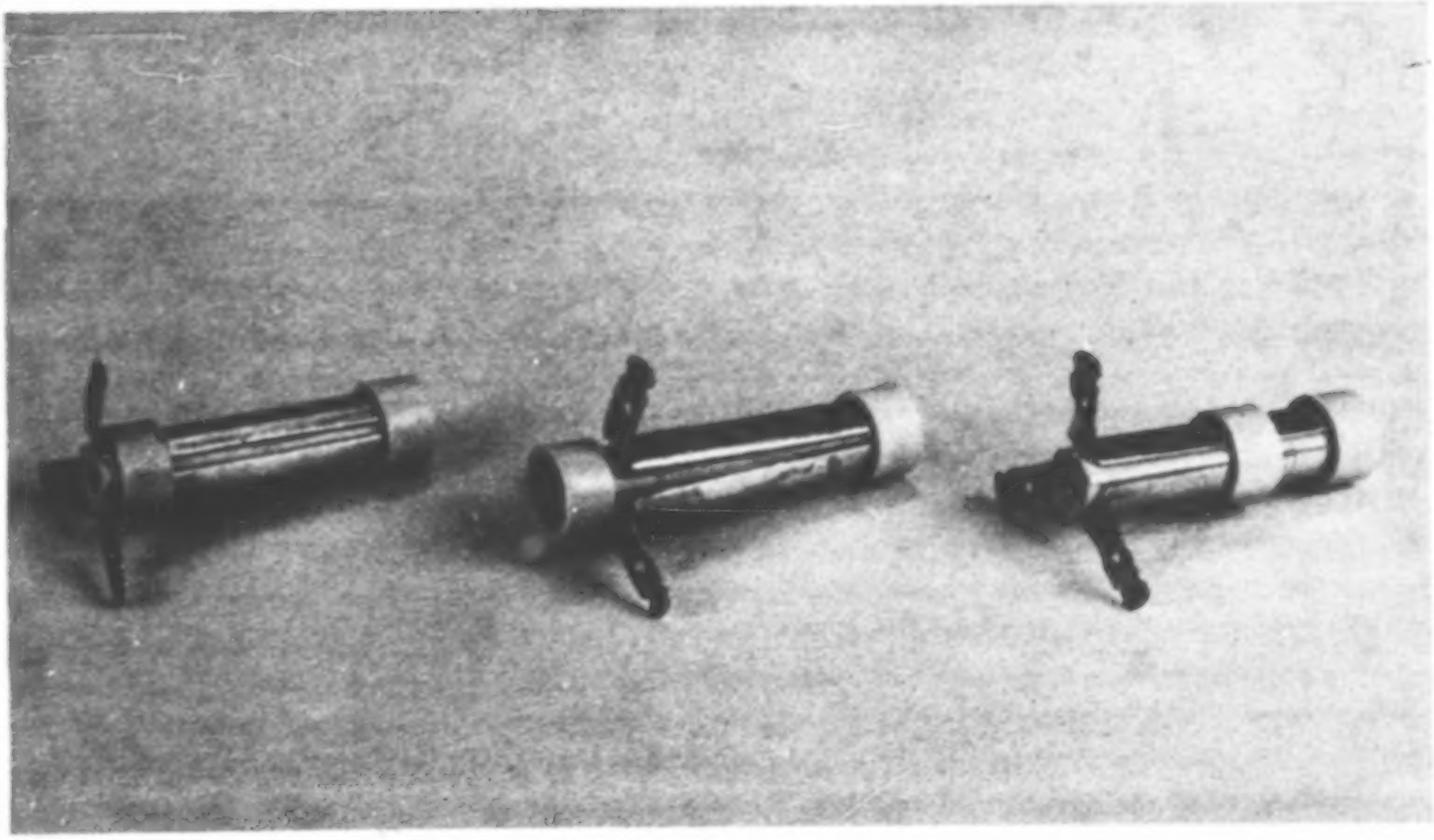
B



☐
A



☐
B



☐ A ☐ B ☐ C

C
BASE PART

NAME____

DATE__________________ SEX____________________

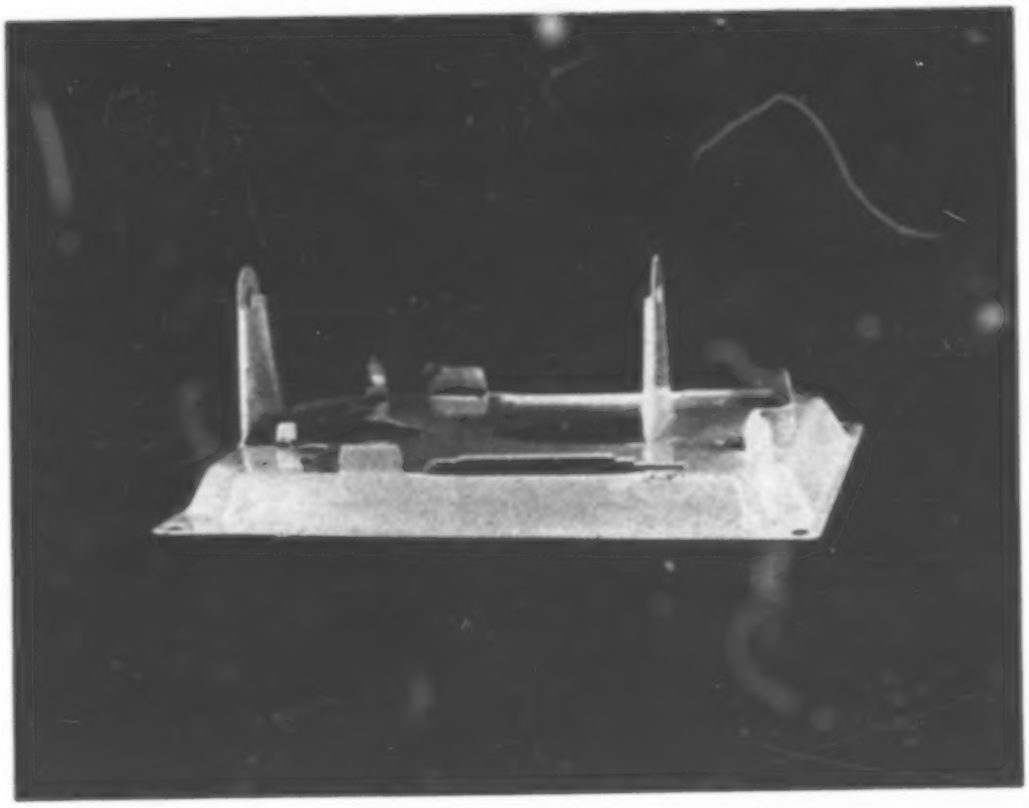
LOCATION______________

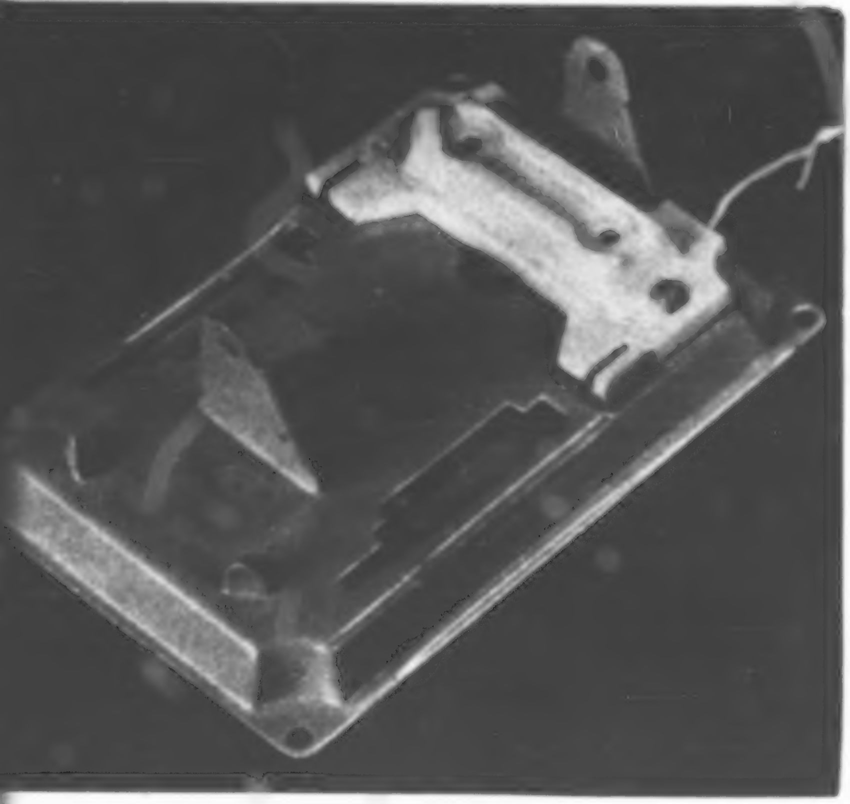
CONDITION______________

☐ A

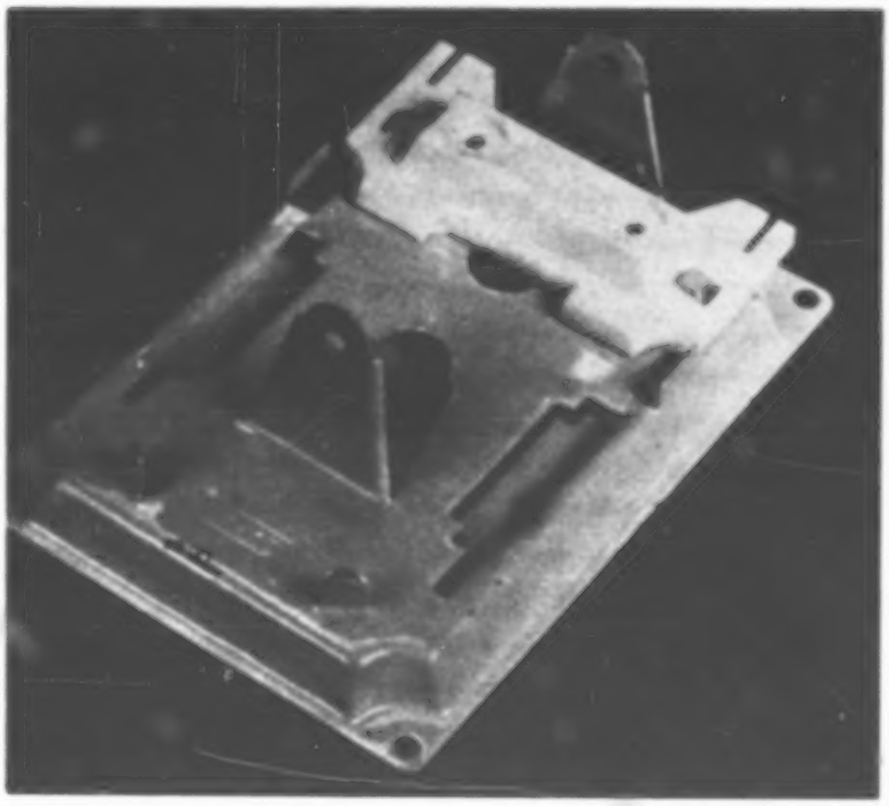
☐ B

☐ C



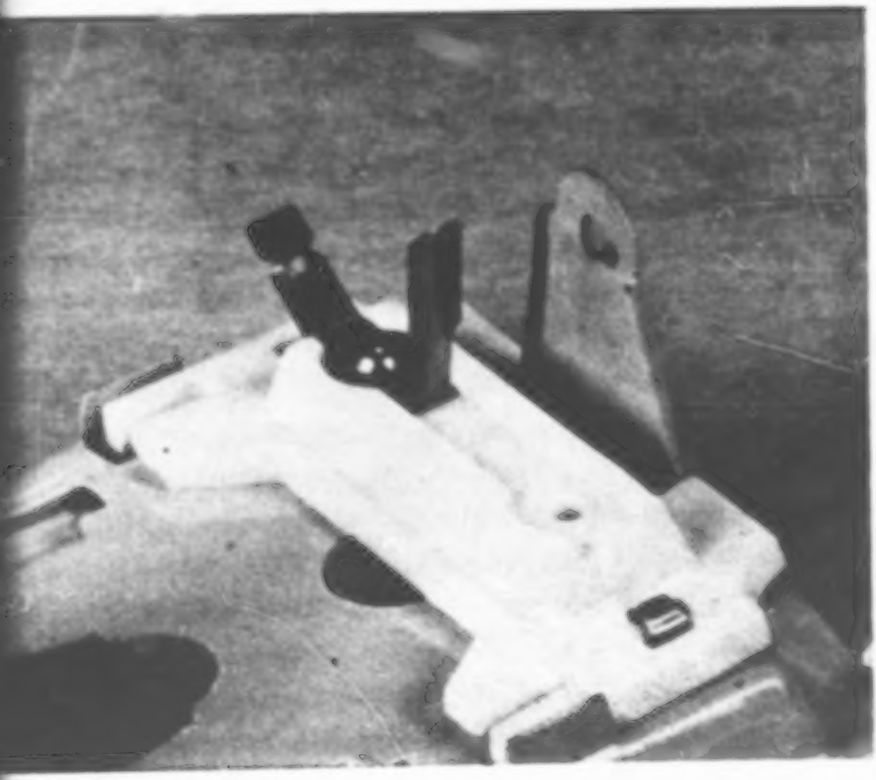


☐
A



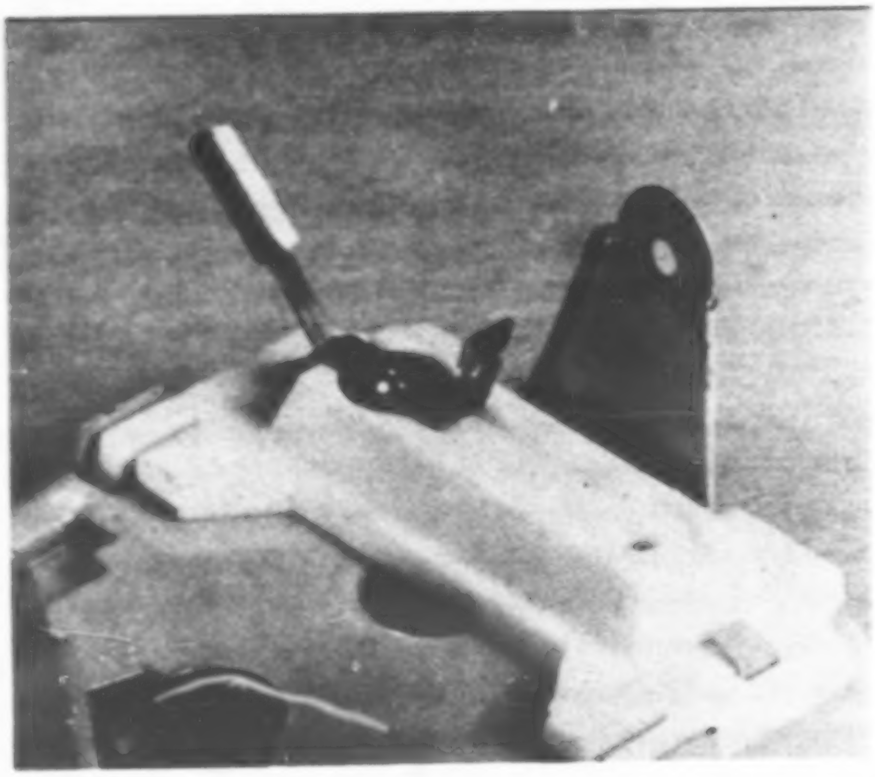
☐
B

C-4



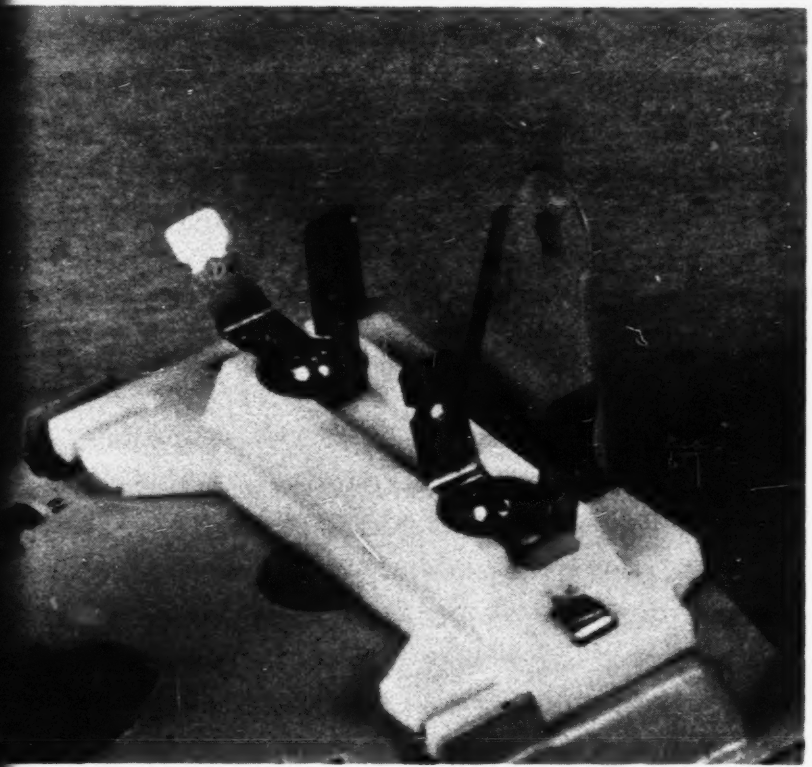
☐

A

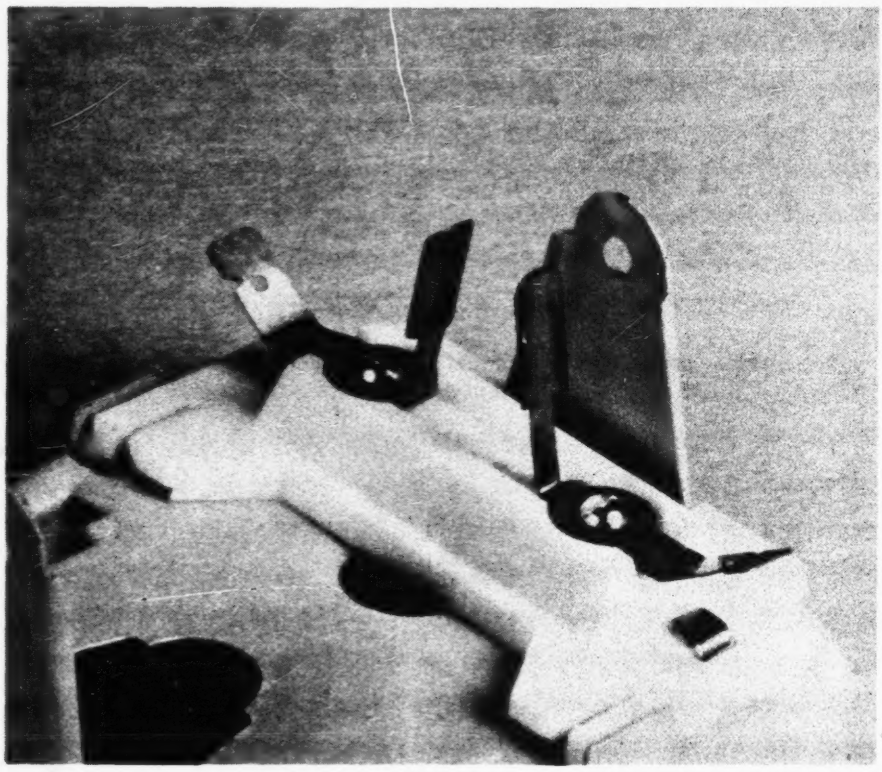


☐

B



☐
A



☐
B

D

CONNECTING MAJOR PARTS

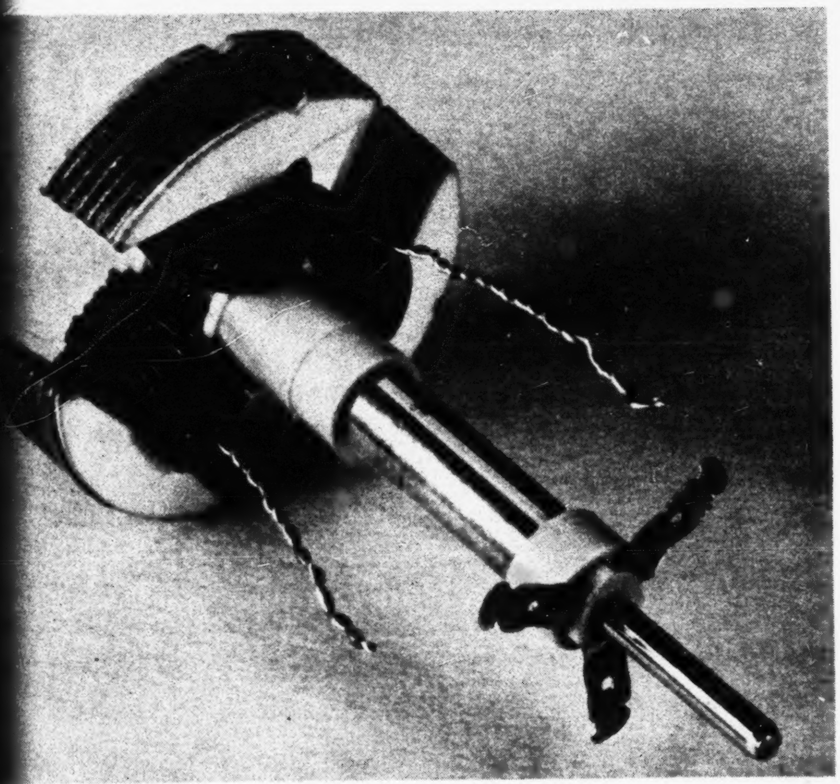
NAME____

DATE____________________ SEX____________________

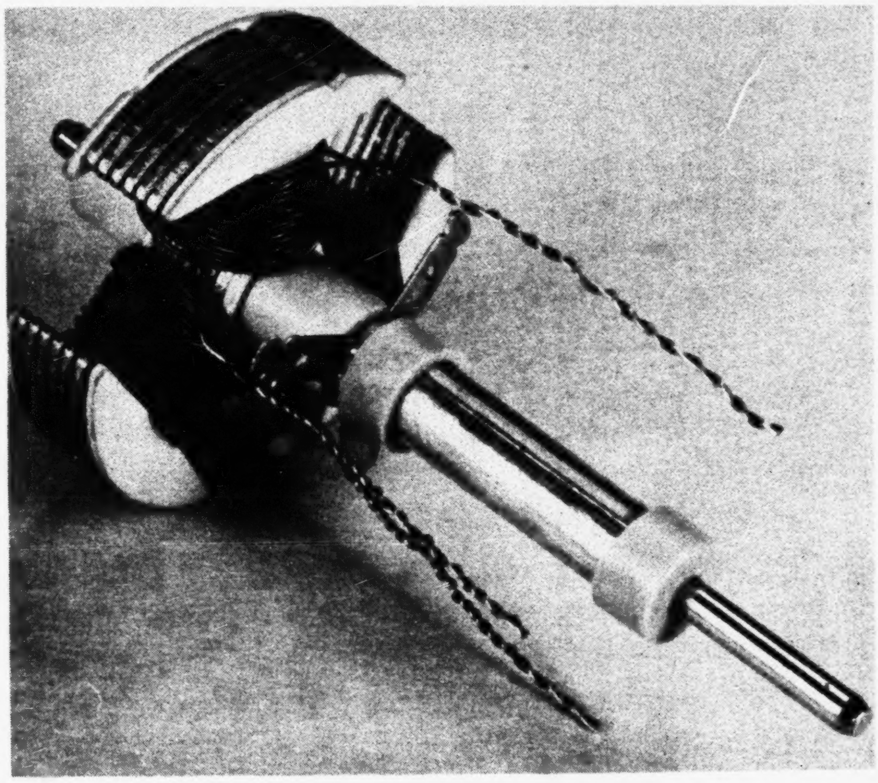
LOCATION________________

CONDITION________________

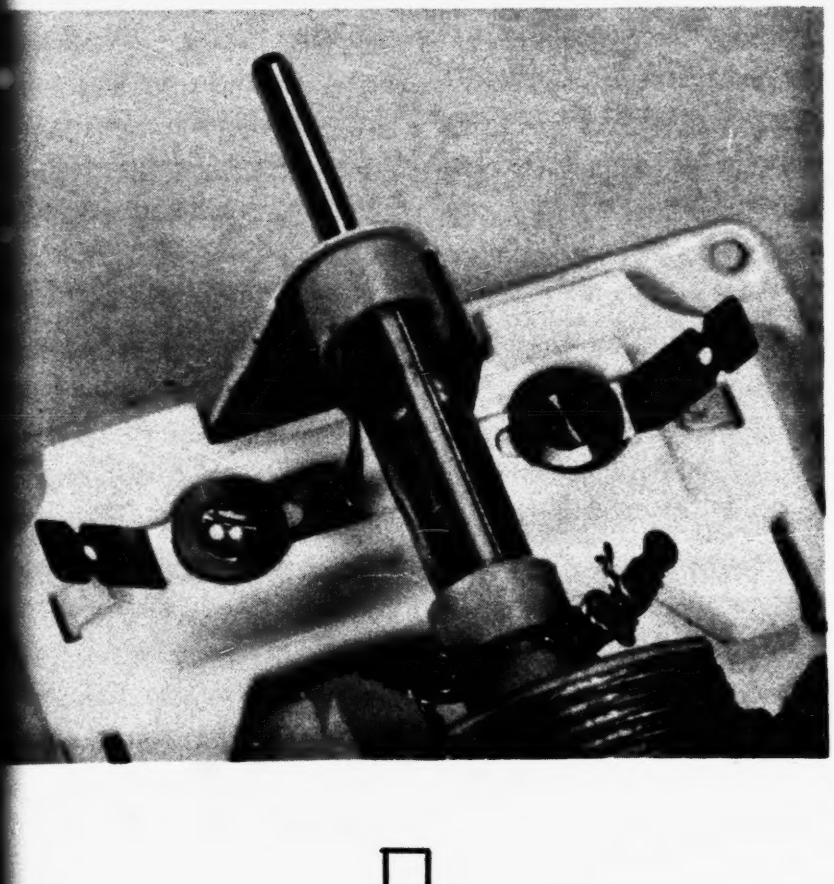
D-1



☐
A

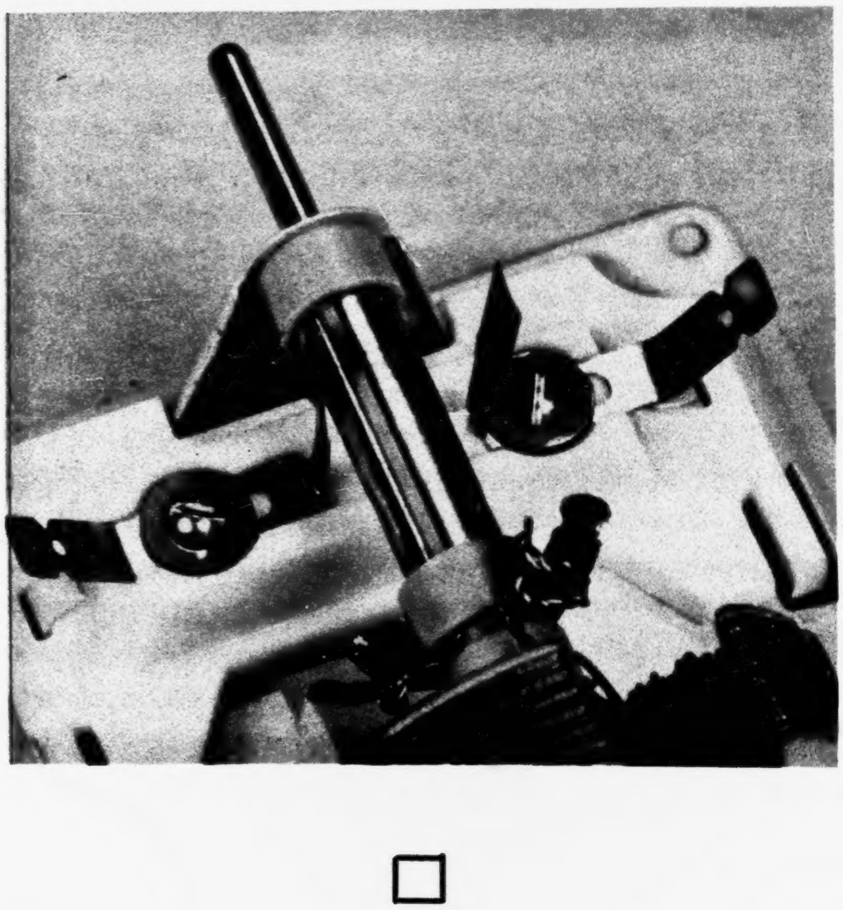


☐
B



☐

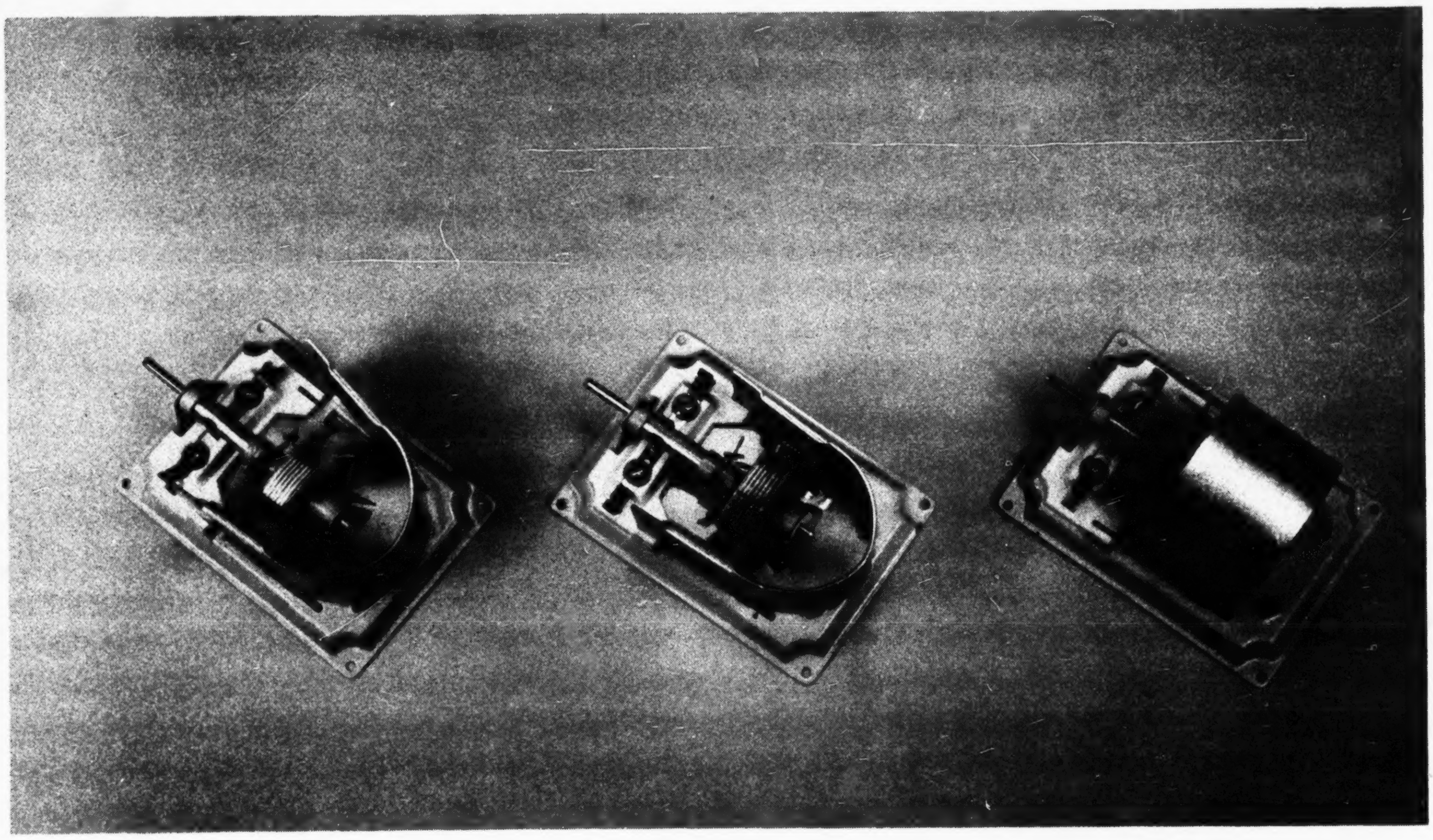
A



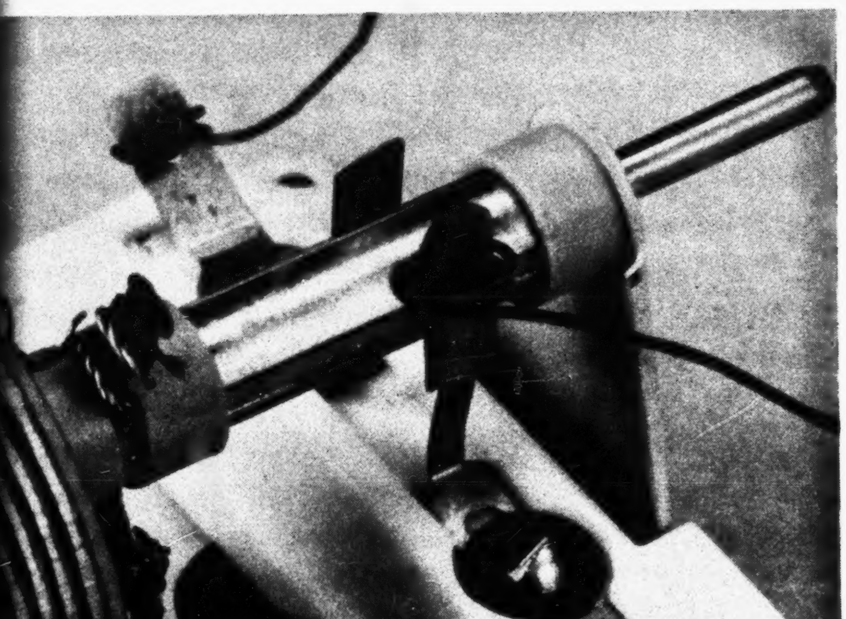
☐

B

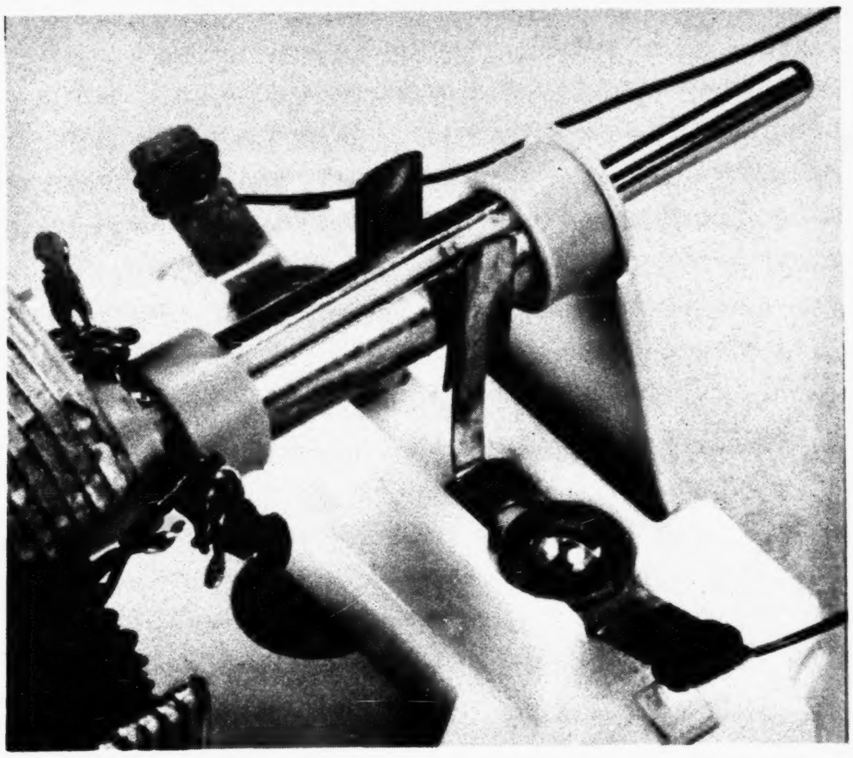
D-3



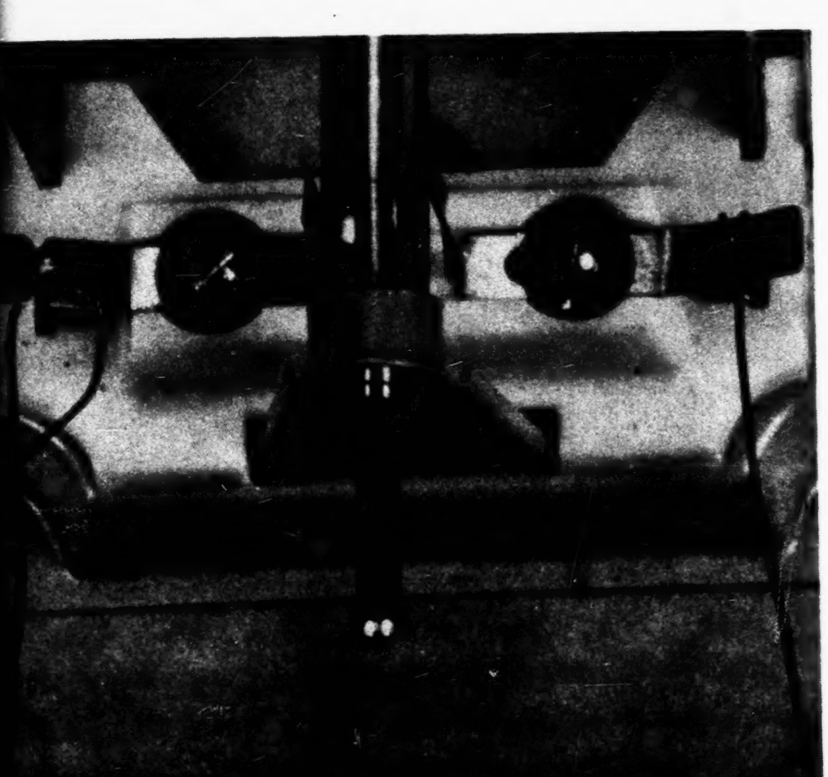
☐ A ☐ B ☐ C



☐
A

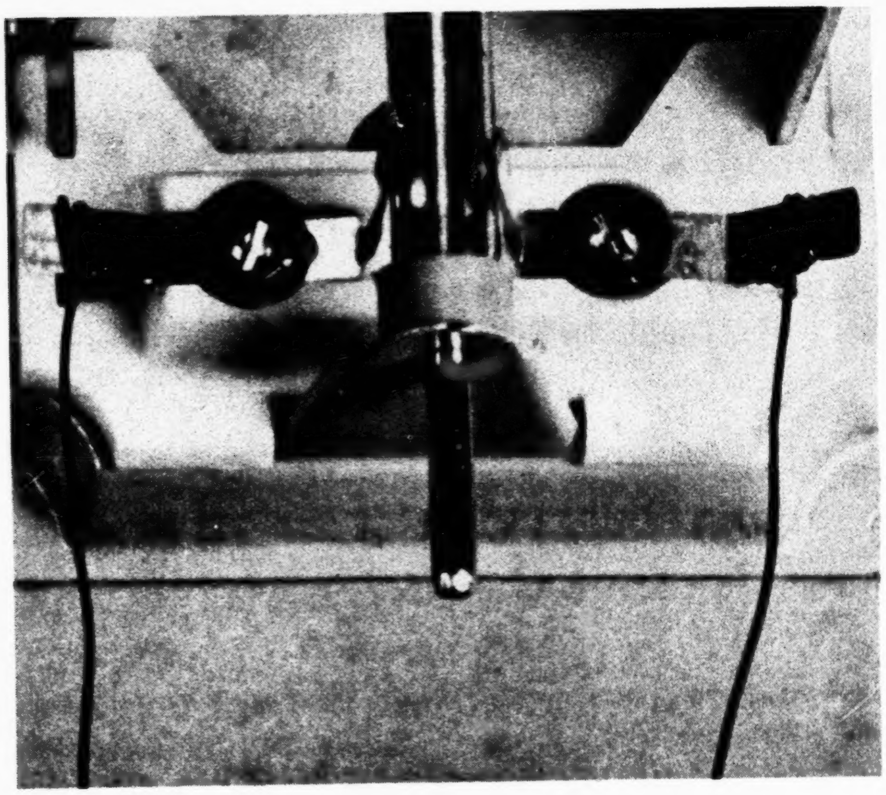


☐
B



☐

A



☐

B

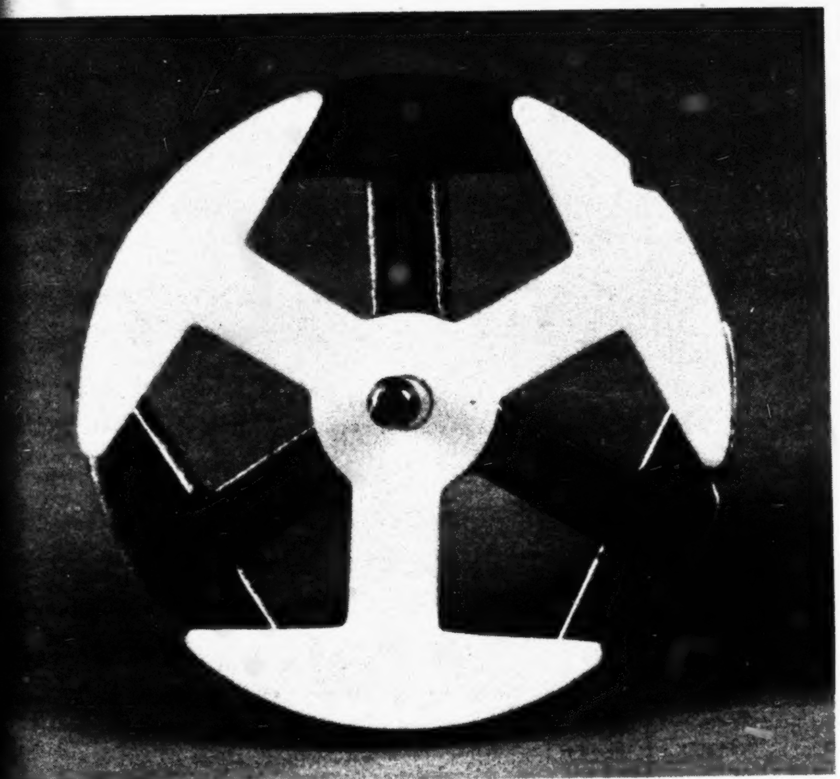
E
TURNING PART PRACTICE

NAME____

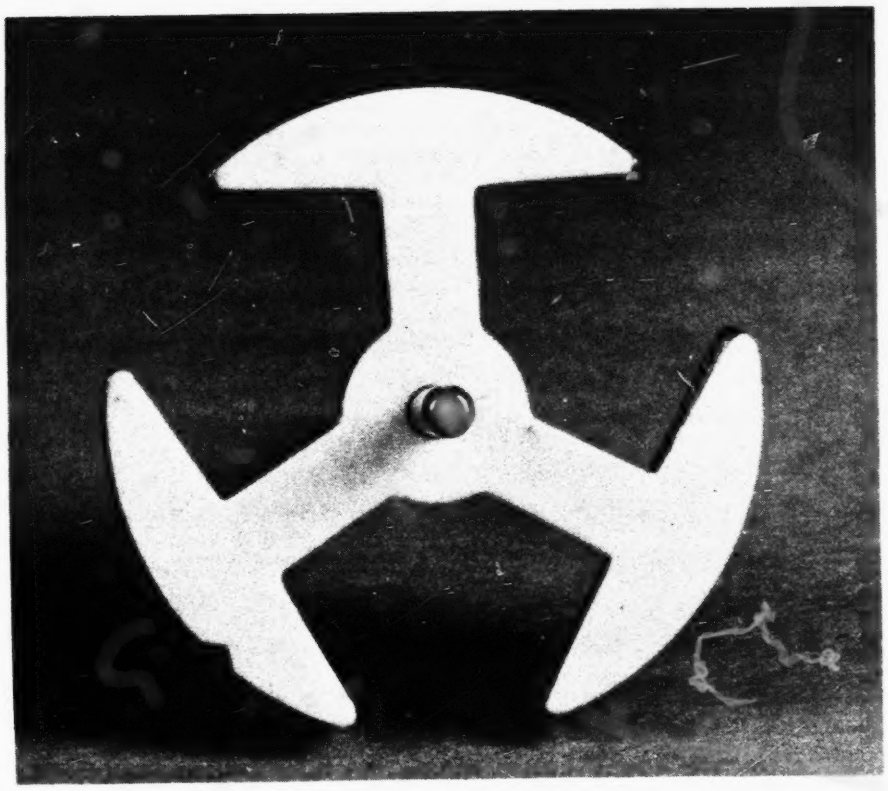
DATE____________________ SEX____________________

LOCATION____________________

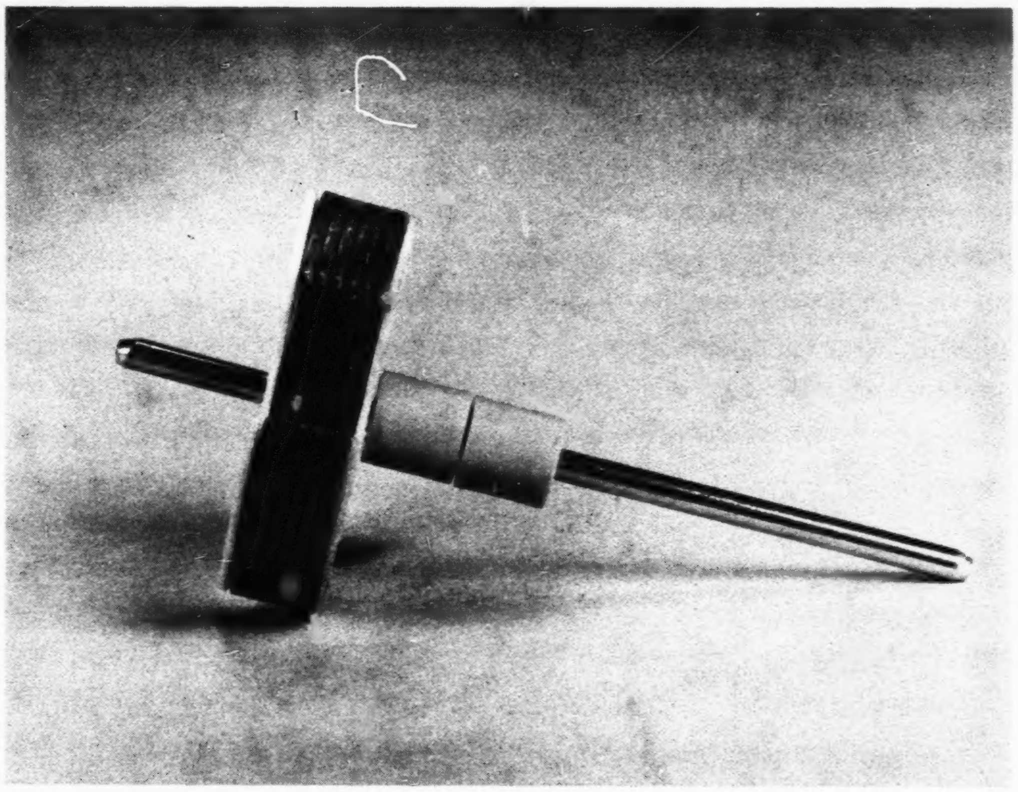
CONDITION____________________



☐
A

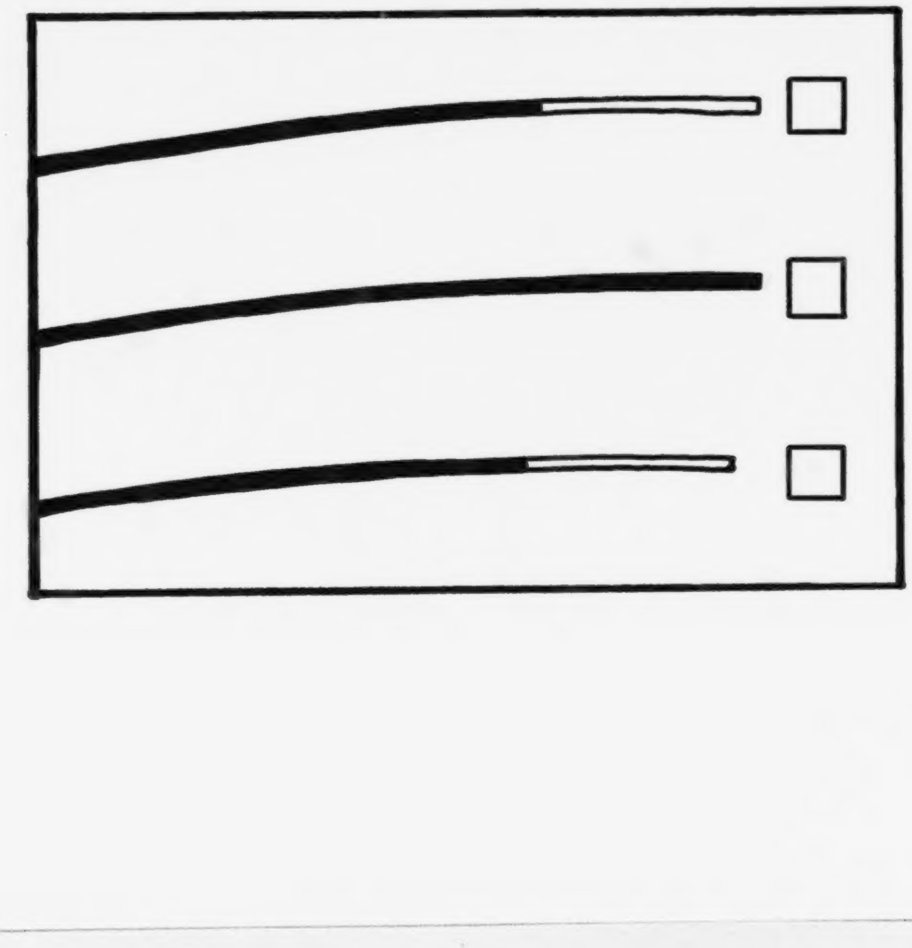


☐
B

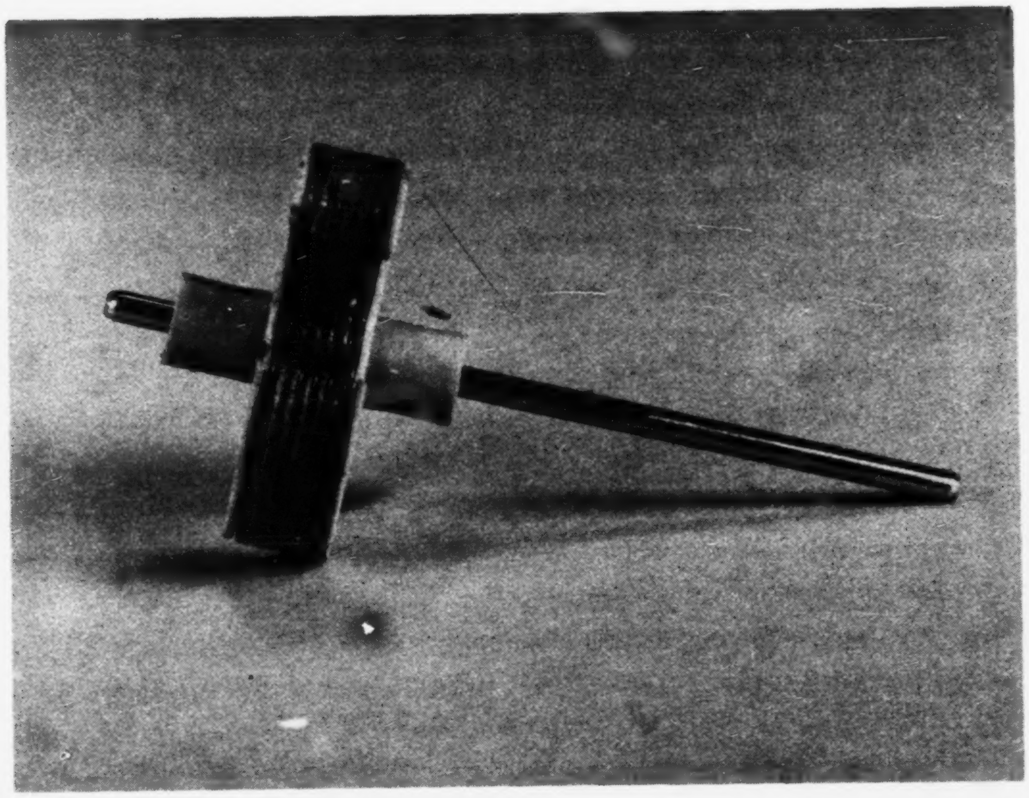


Is this turning part correctly assembled?

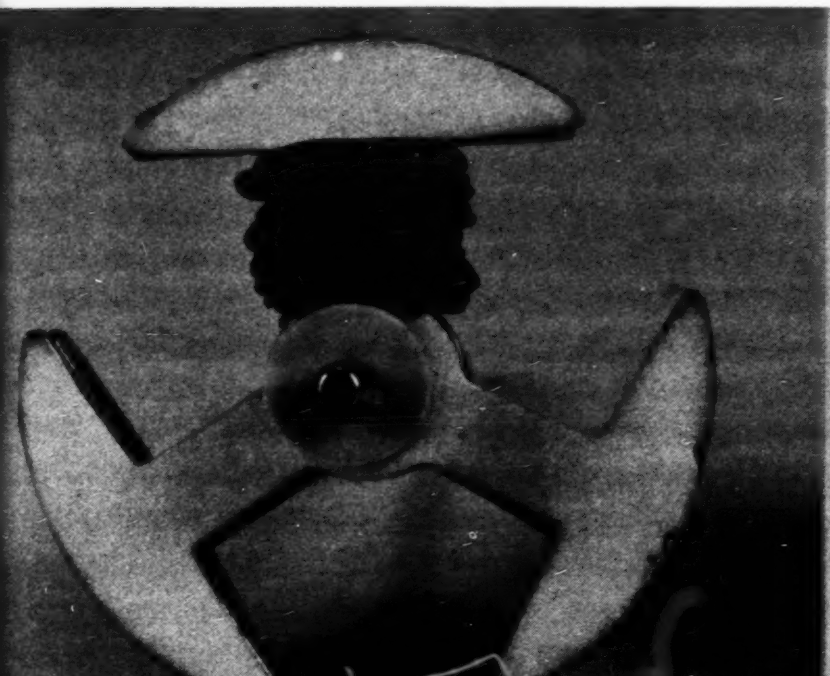
☐ YES ☐ NO



E-4

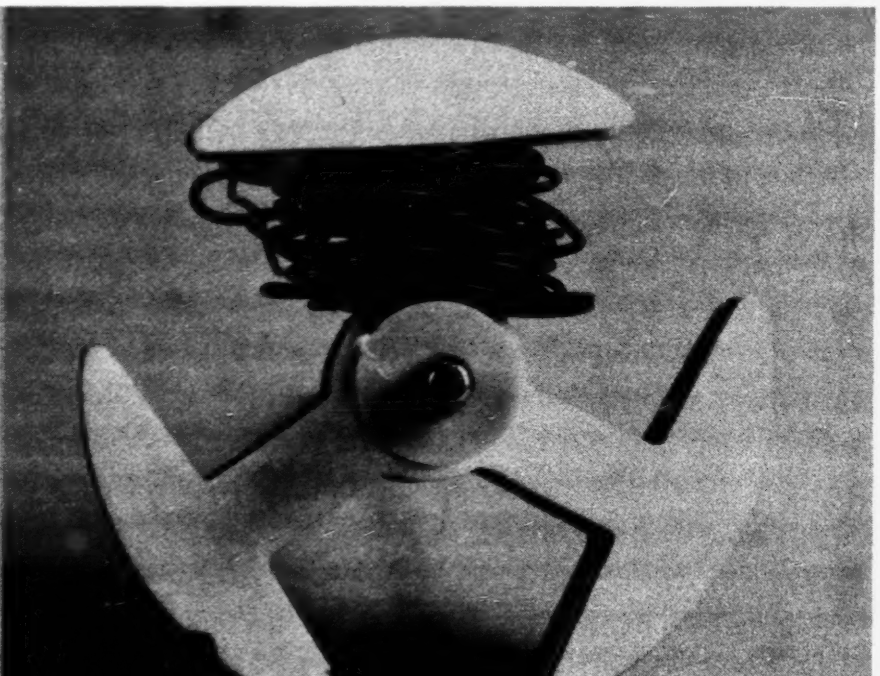


☐ ☐



☐

A



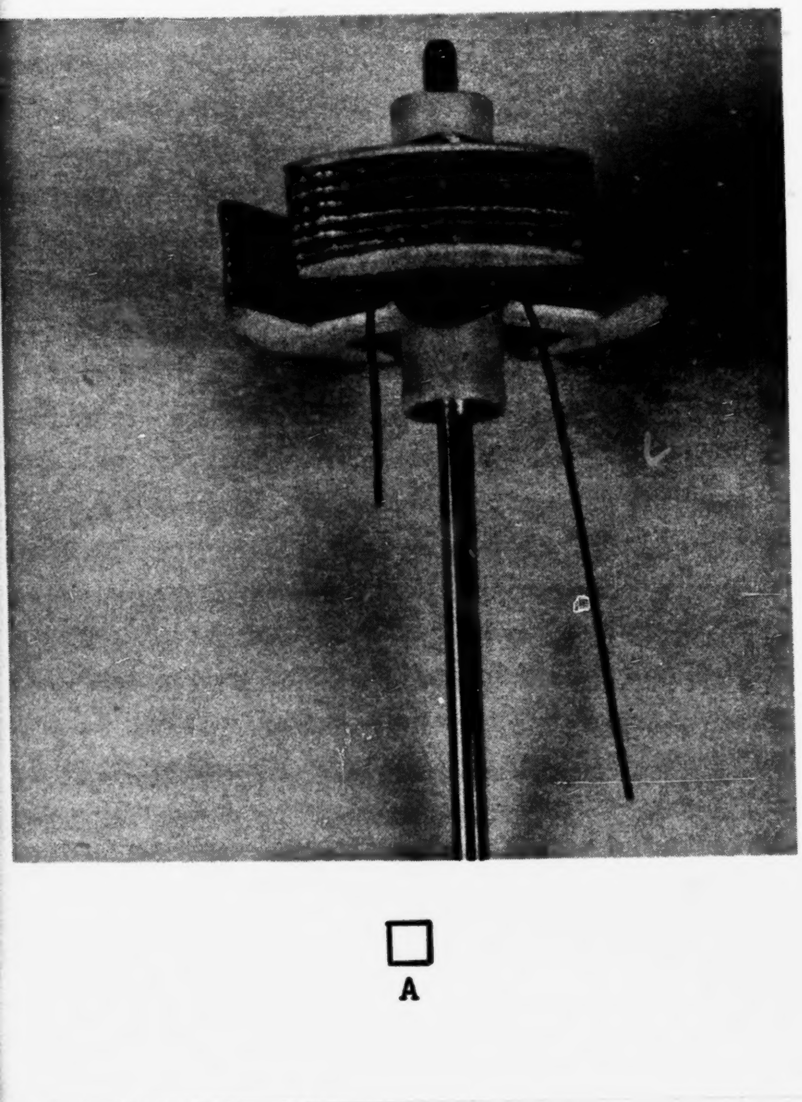
☐

B

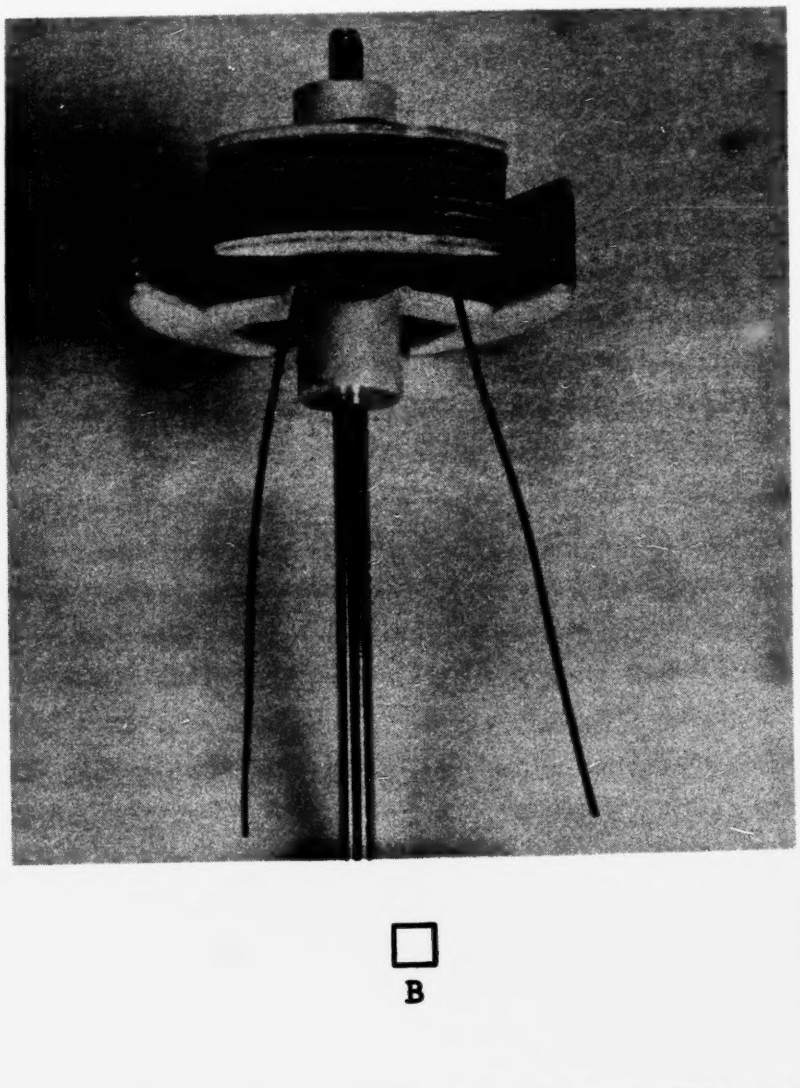
Were the wires correctly wound?

☐ Yes

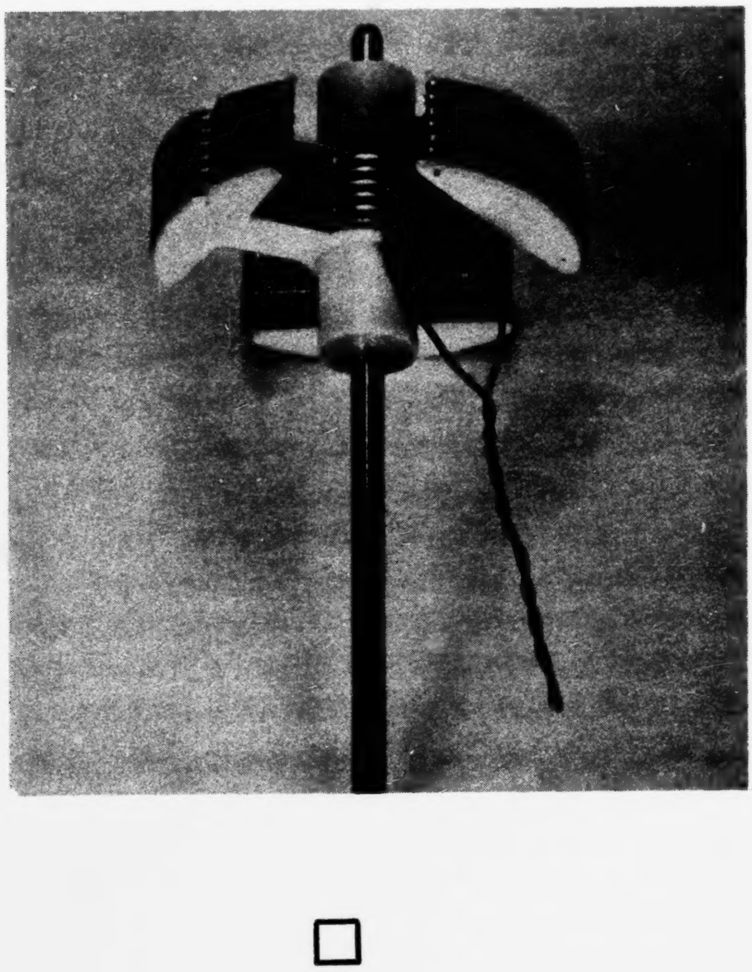
☐ No



A

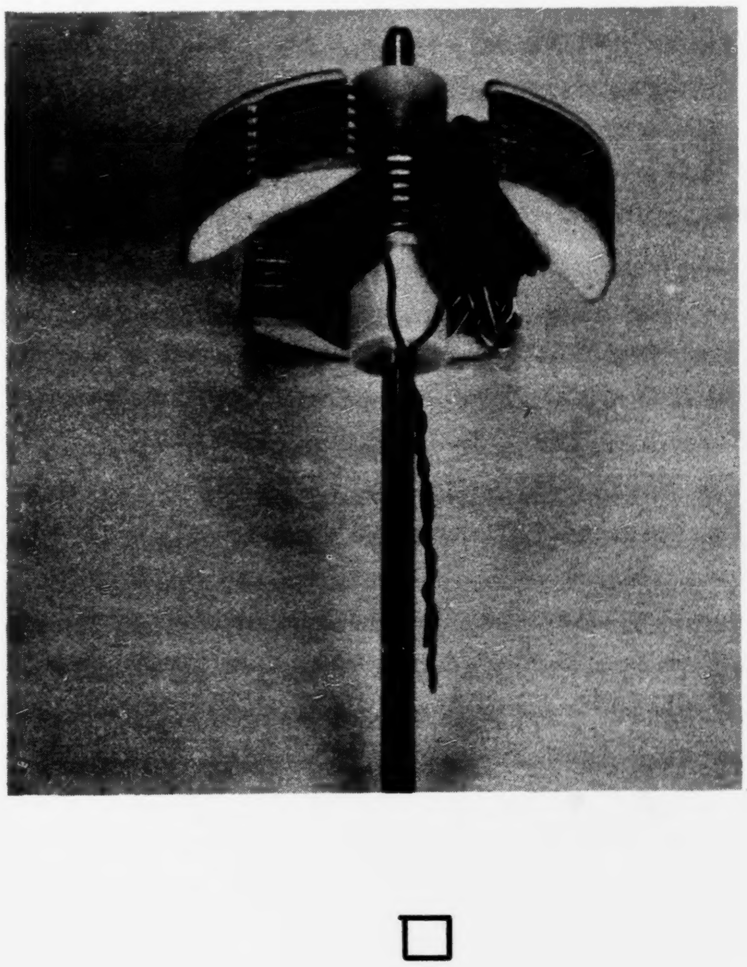


B



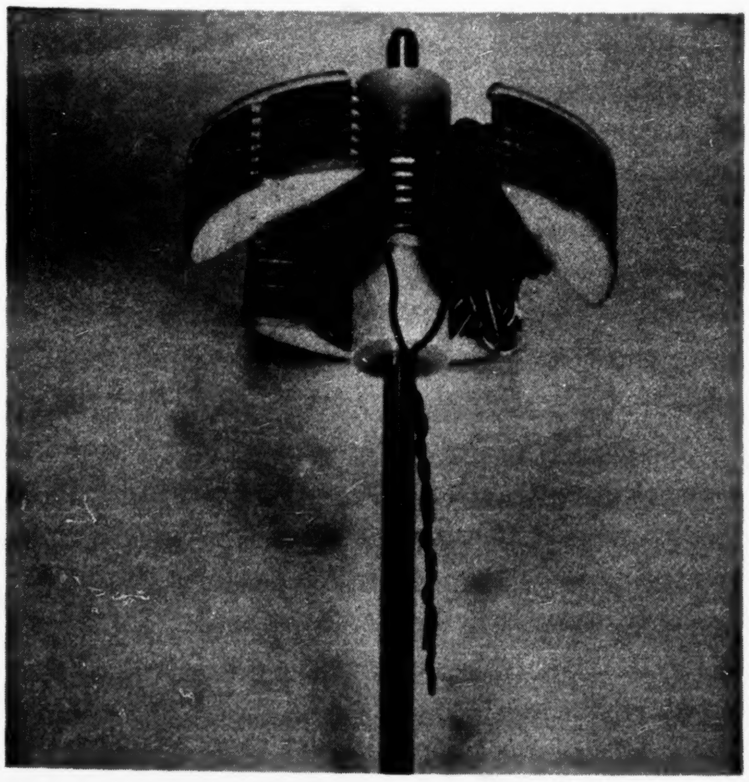
☐

A



☐

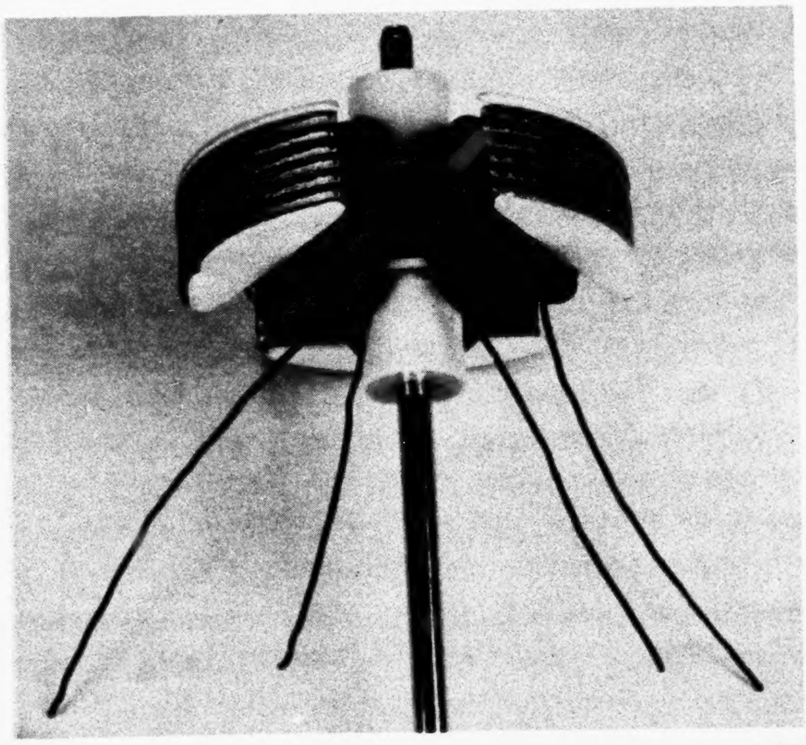
B



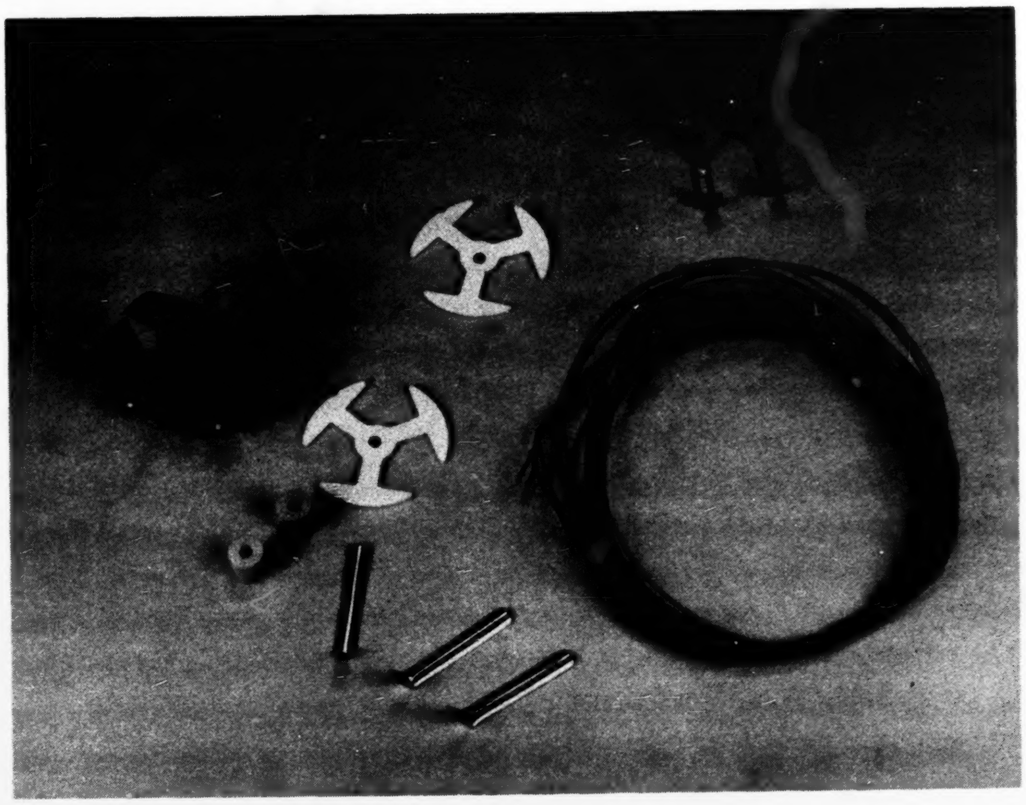
Are the correct wires twisted together?

☐ Yes

☐ No



☐ A ☐ B ☐ C ☐ D



Circle all the small parts that make up the turning part.

F

TUBE PART PRACTICE

NAME____

DATE__________________ SEX__________________

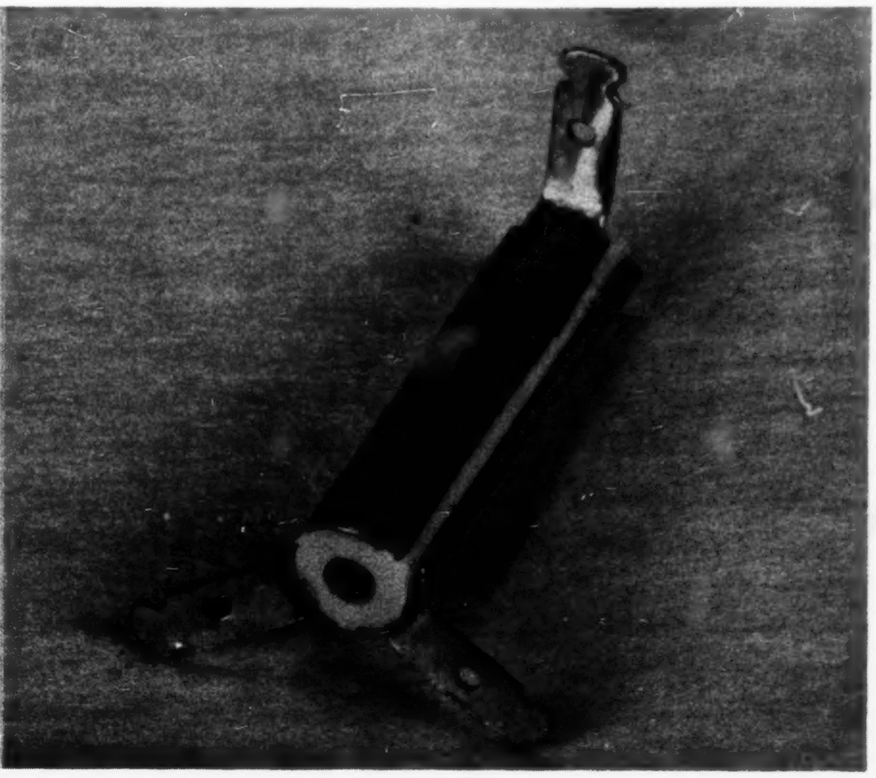
LOCATION________________

CONDITION_______________

F-1

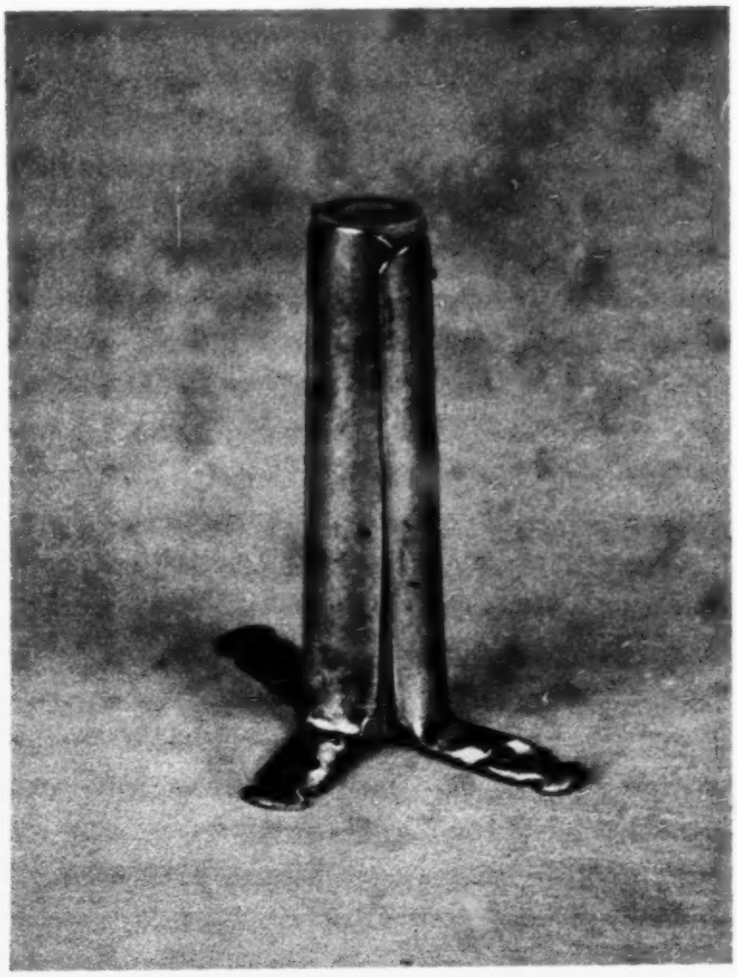
☐

A



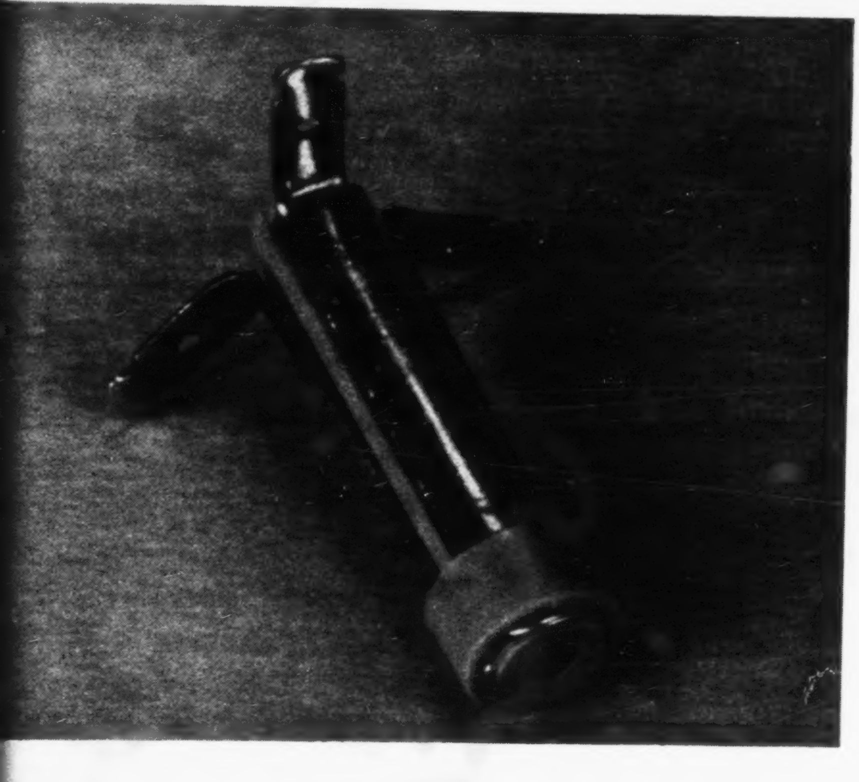
☐

B

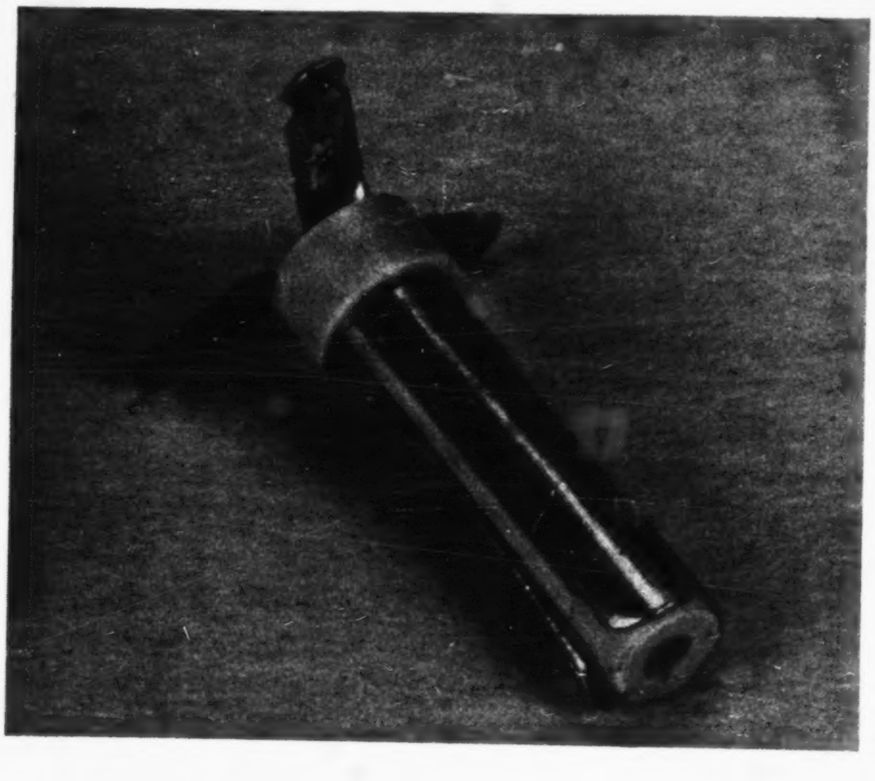


Are the metal strips correctly placed around this tube?

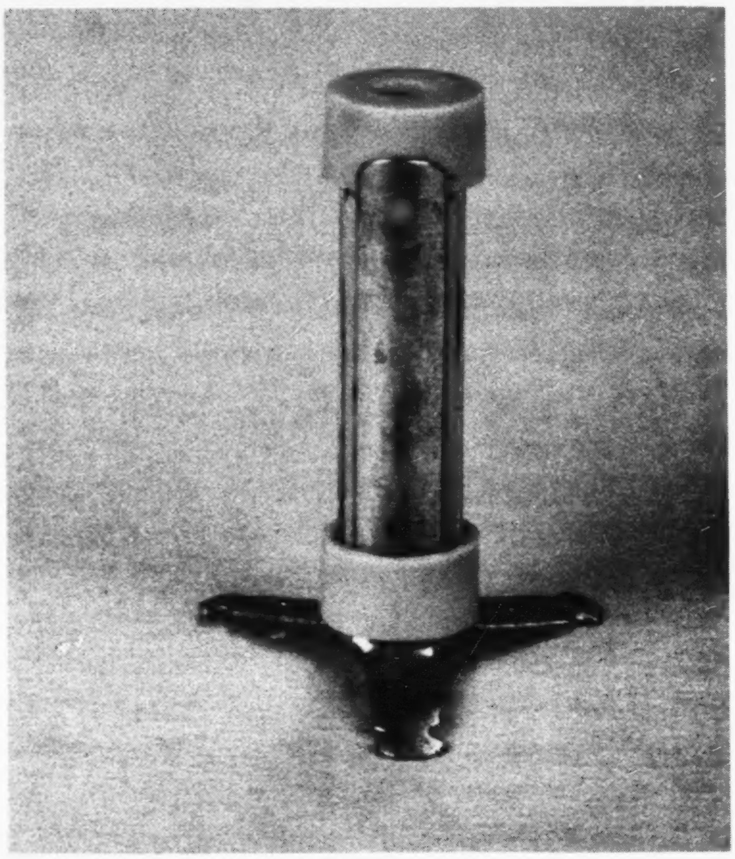
Yes No



☐
A

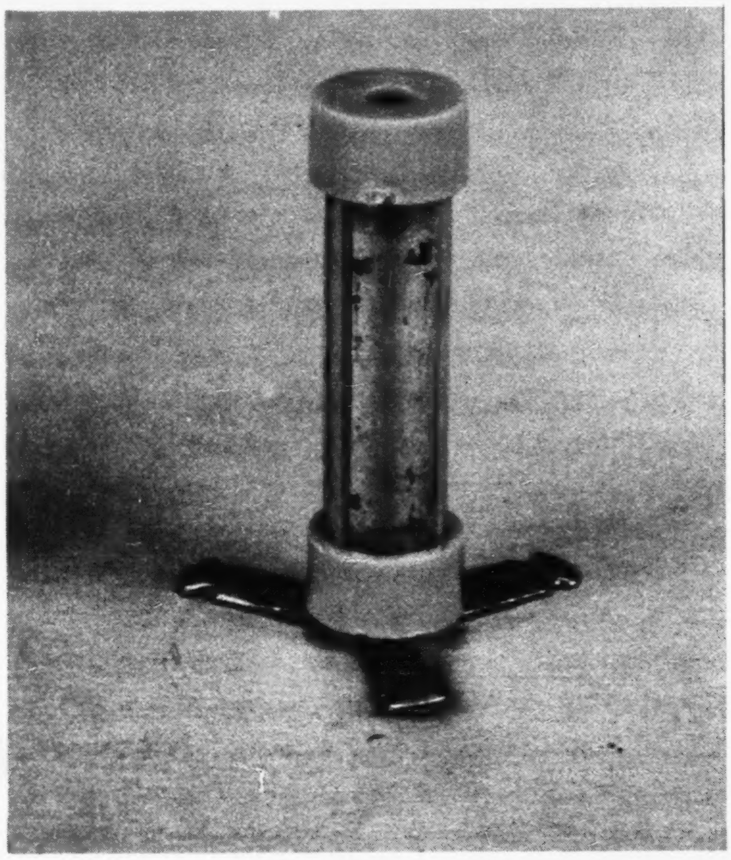


☐
B



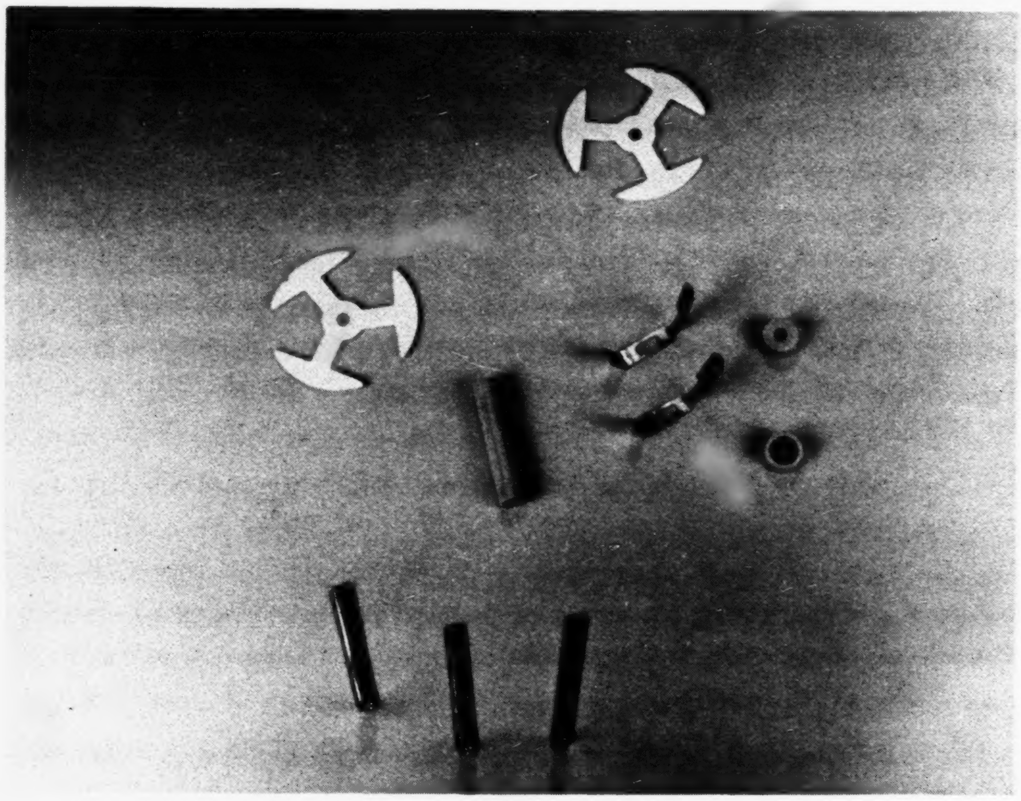
☐

A



☐

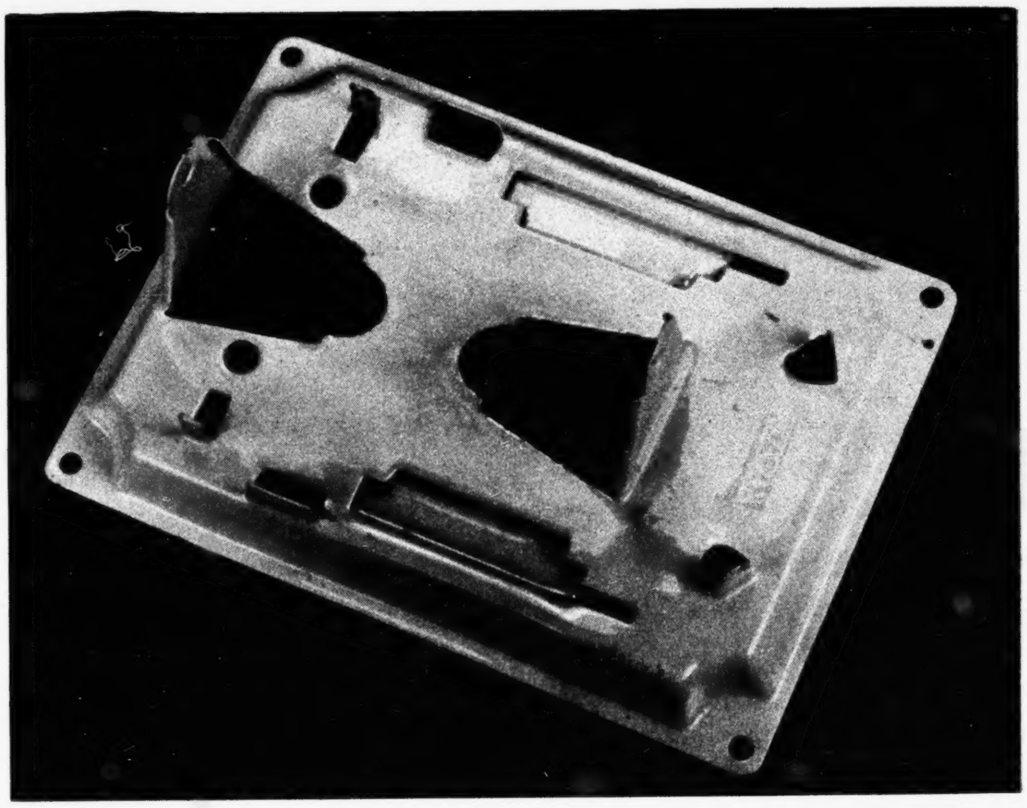
B

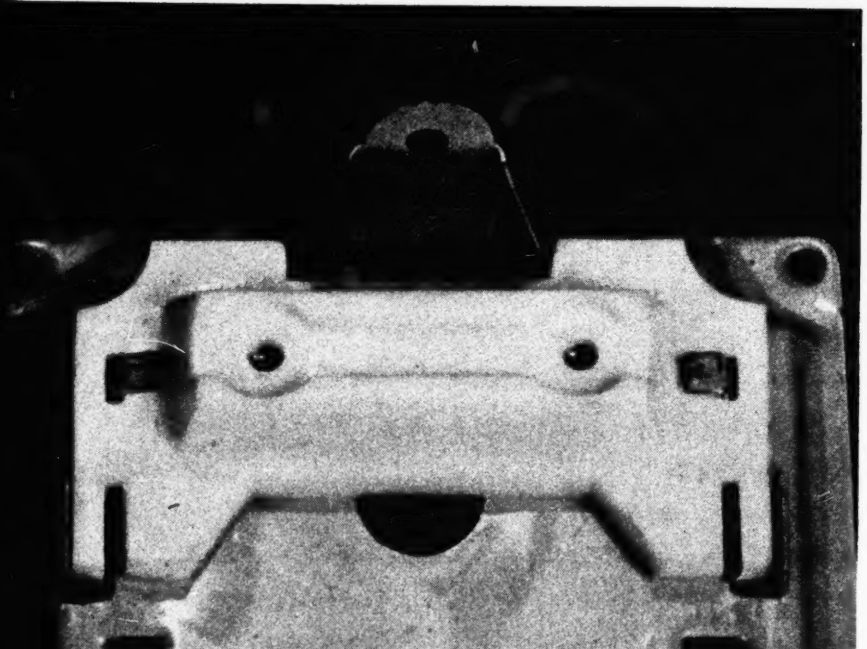


Circle all the small parts that make up the tube part.

G
BASE PART PRACTICE

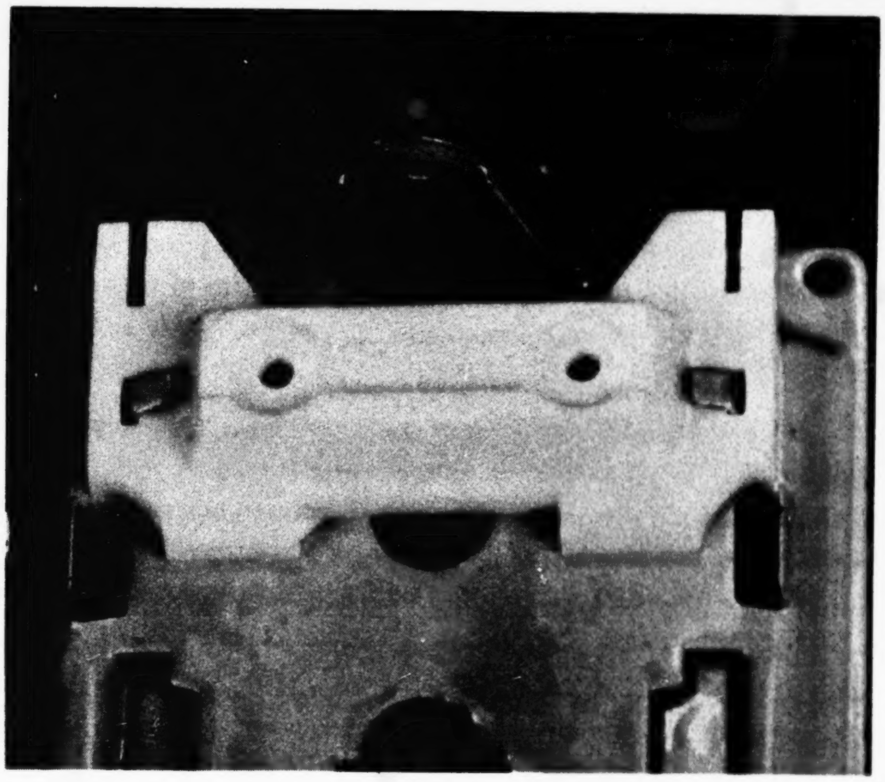
NAME			
DATE		SEX	
LOCATION			
CONDITION			





☐

A



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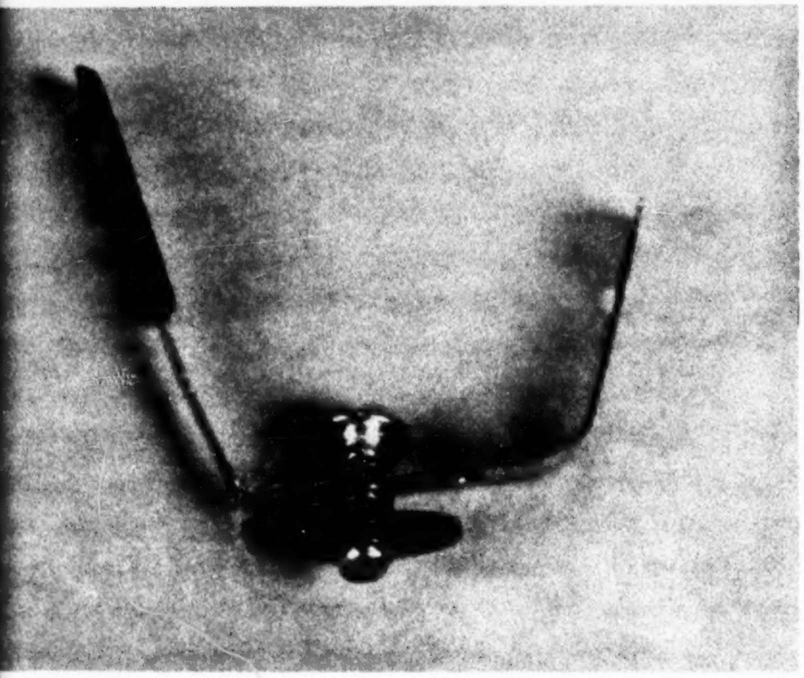

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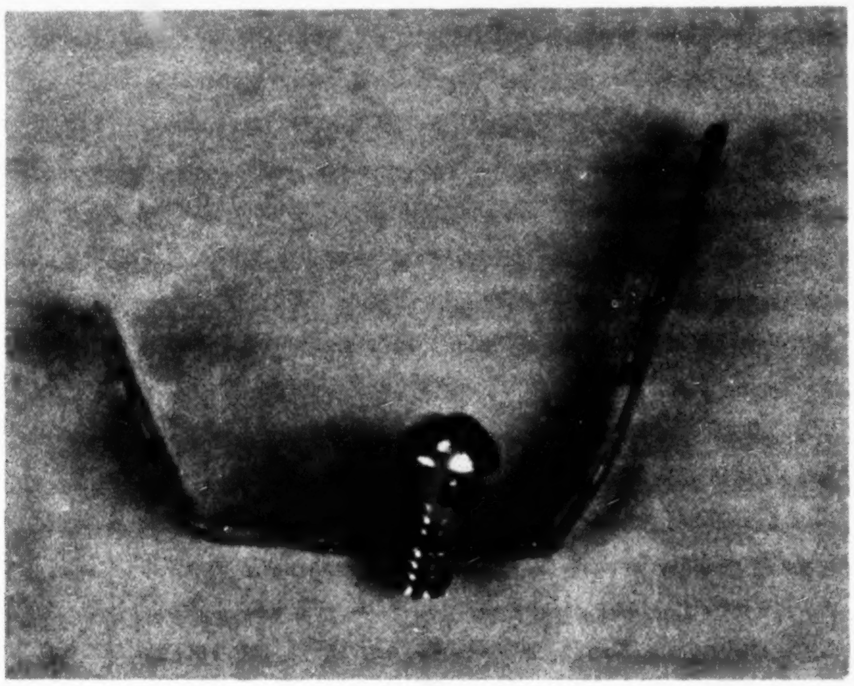

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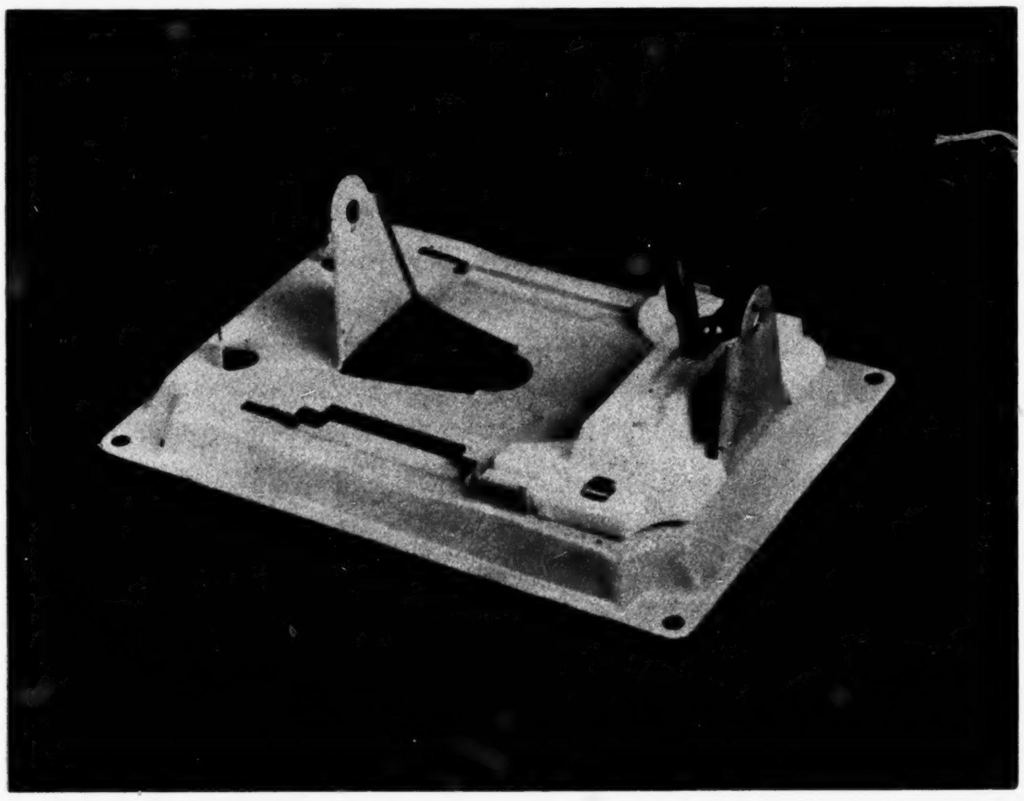
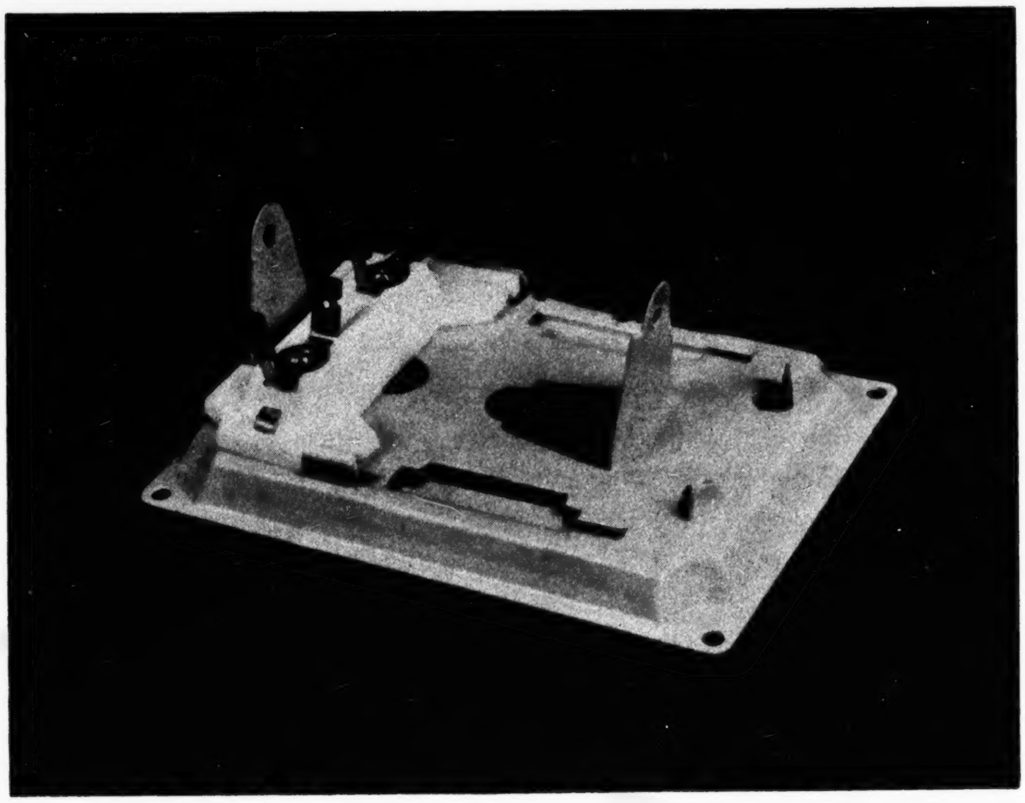


Is the piece of copper correctly attached to the platform?

☐ YES

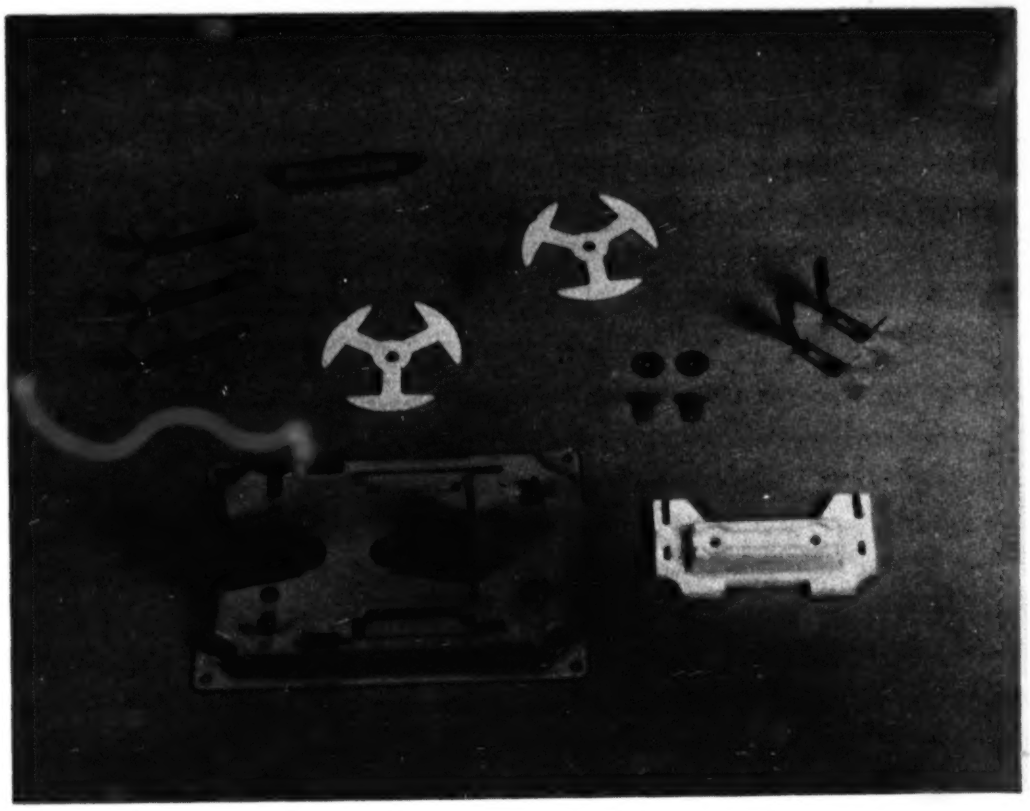
☐ NO



Are both pieces of copper put on the platform correctly?

☐ YES

☐ NO



Circle all the parts that make up the base.

H
CONNECTING MAJOR PARTS PRACTICE

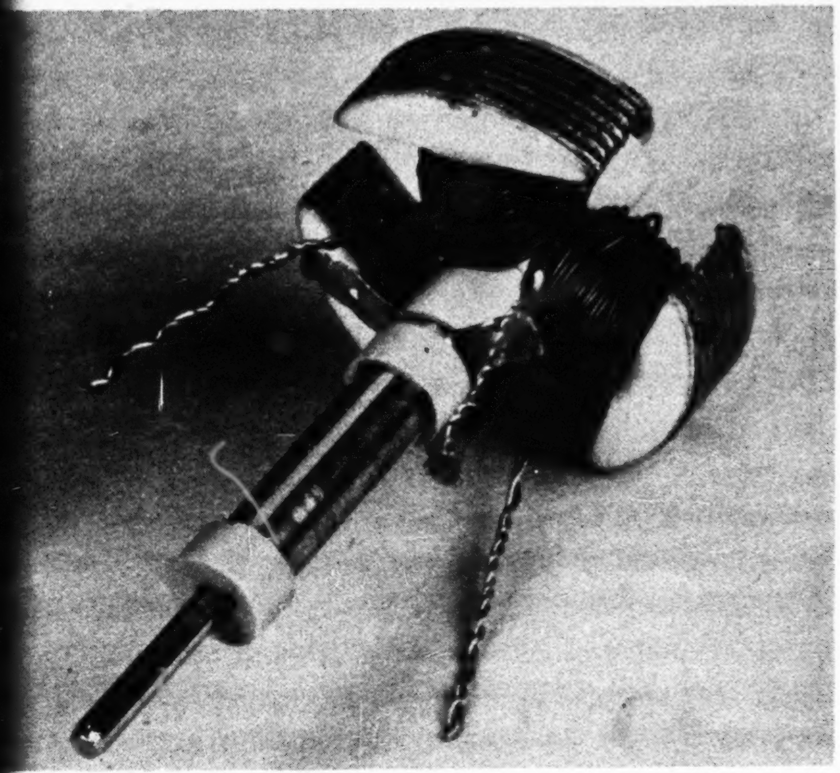
NAME____________________

DATE__________ SEX__________

LOCATION__________

CONDITION__________

H-1



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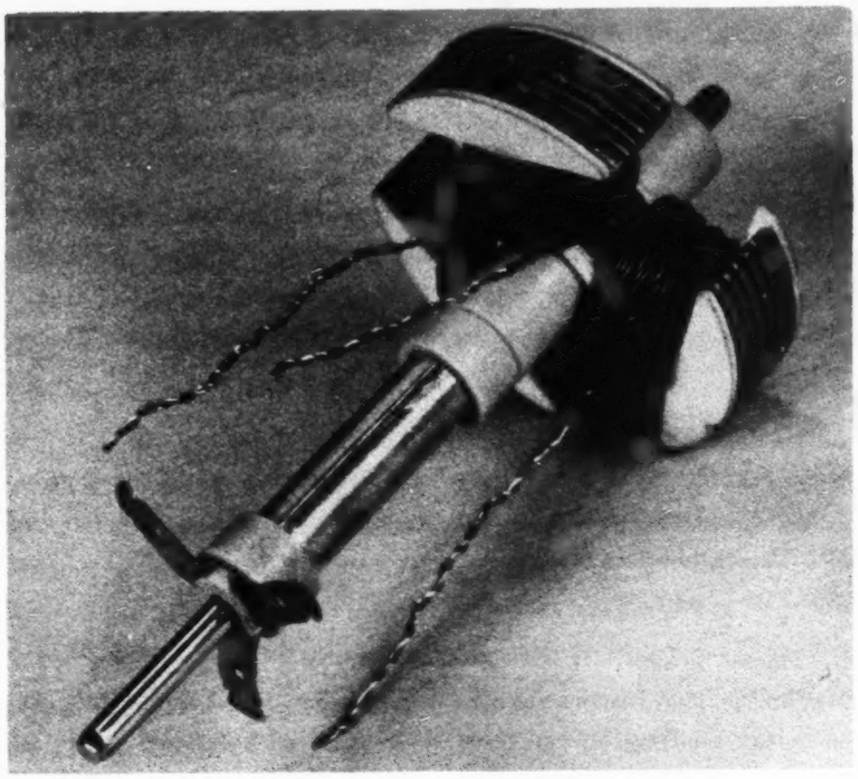

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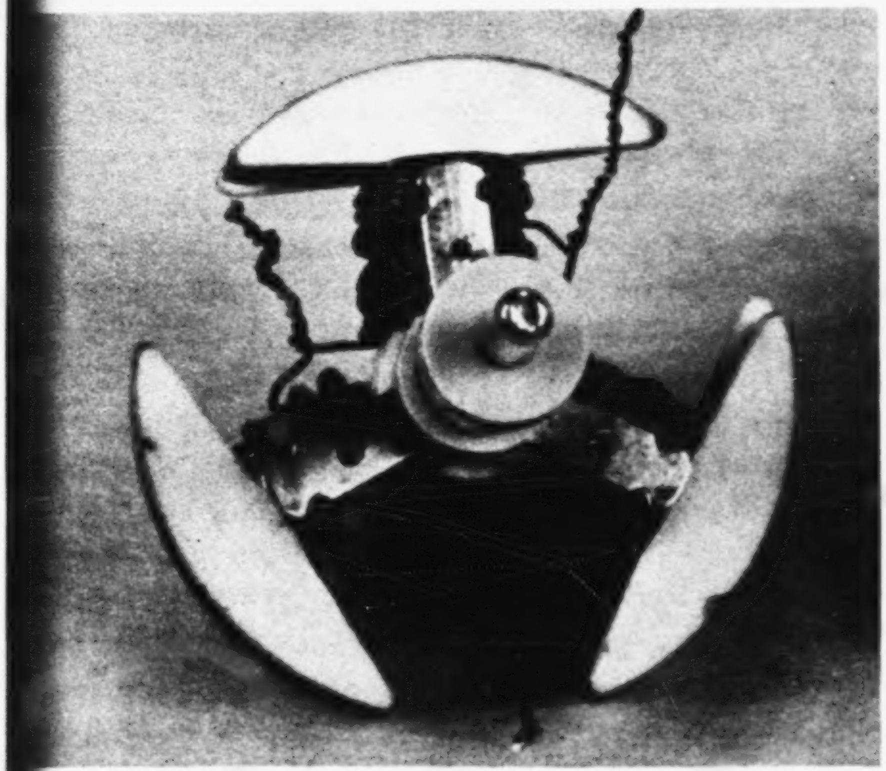

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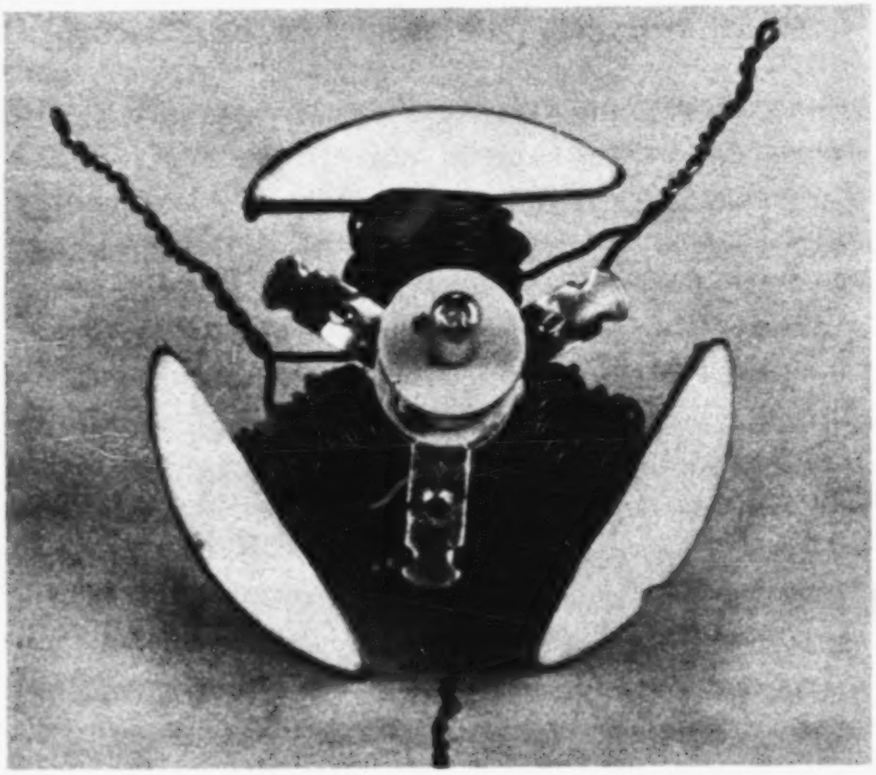

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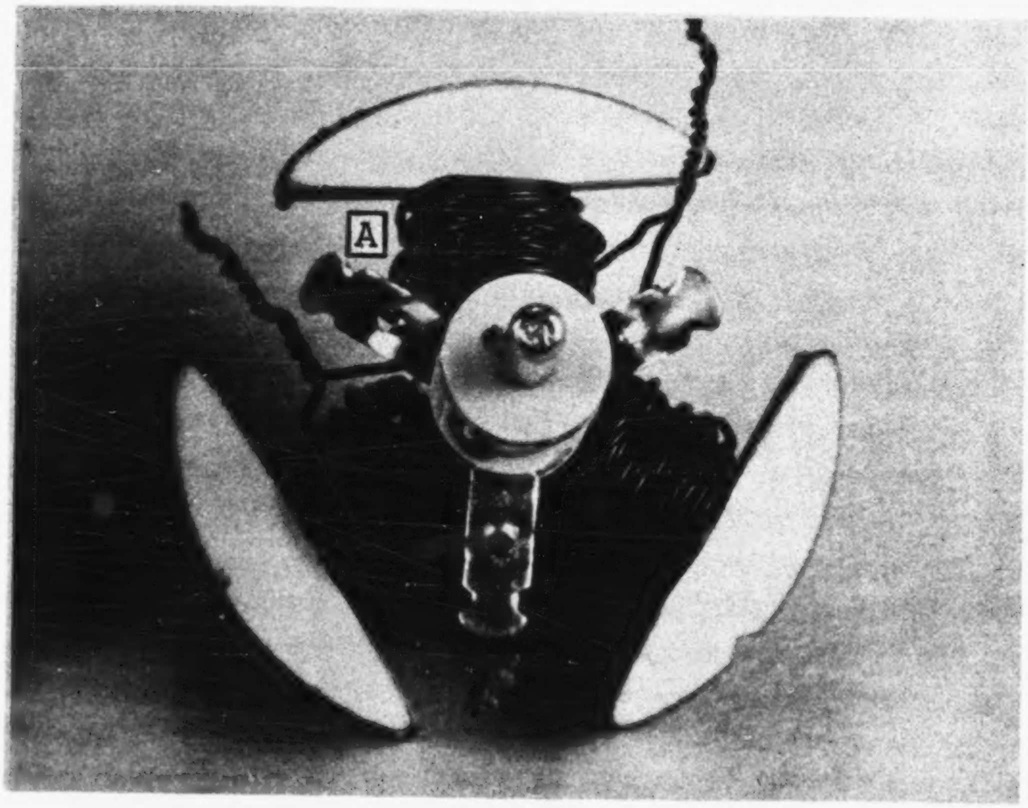
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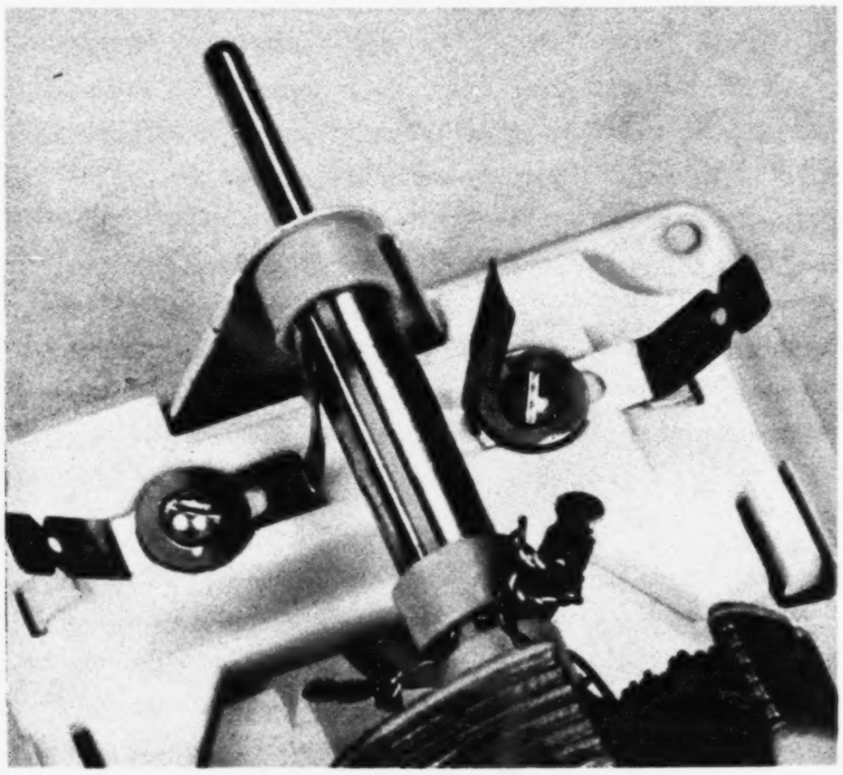
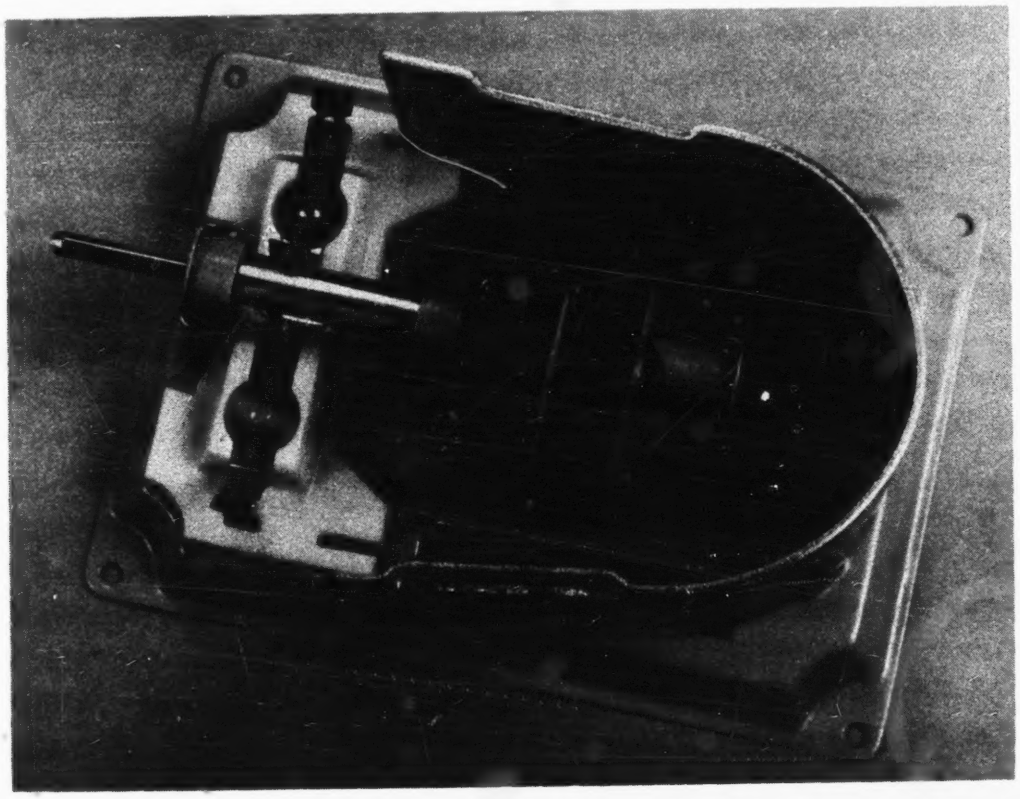


Are the bent pieces of copper in the correct position?

☐ Yes

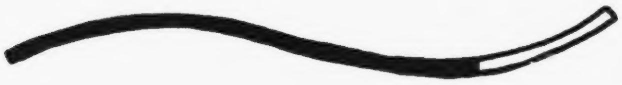
☐ No



Is this magnet put on the base correctly?

☐ Yes

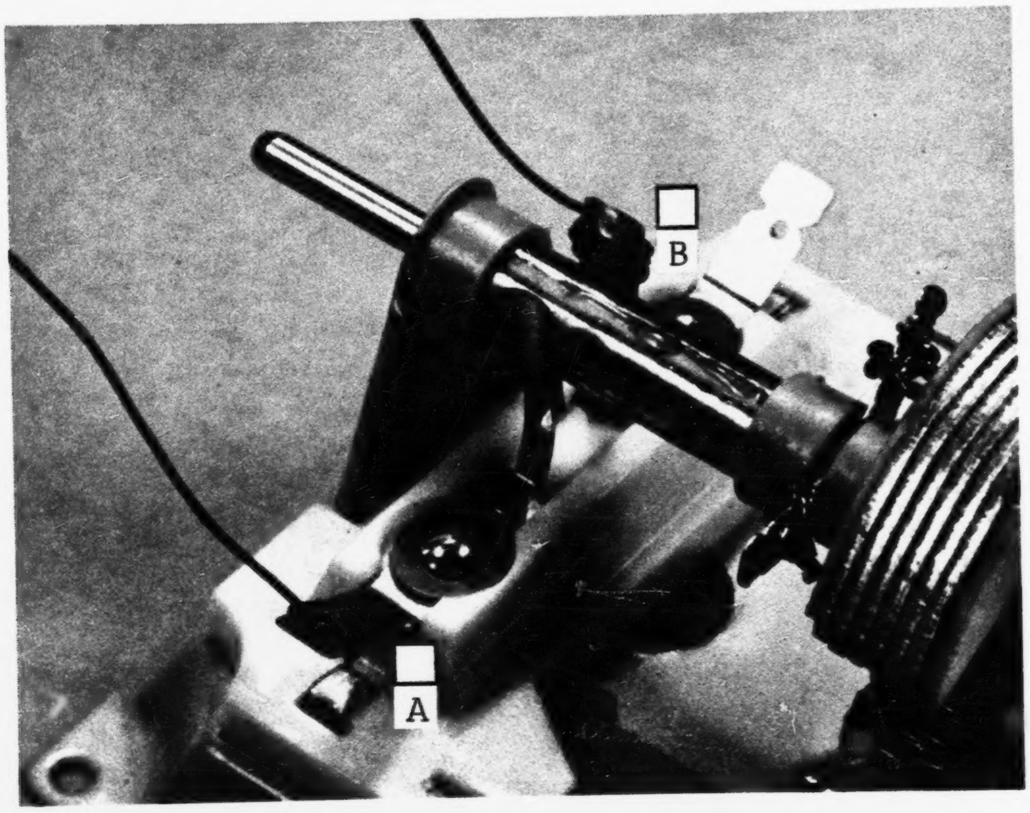
☐ No



Is this wire ready to be attached to the copper strip on the platform?

☐ Yes

☐ No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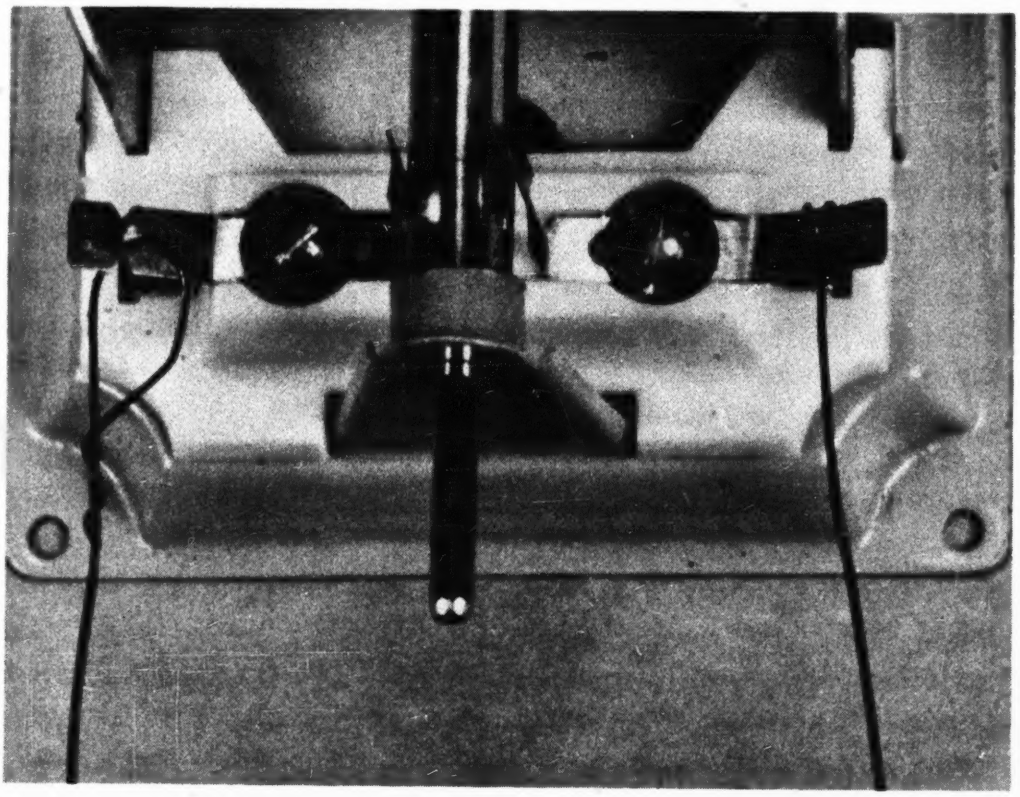

☐ ☐

APPENDIX D

Observer Form for Recording Student Errors on Motor Assembly

TURNING PART

NAME ____________________
DATE ____________ SEX ________
LOCATION ____________________
CONDITION ____________________
PROCTOR ____________________

BEGAN AT ____________
FINISHED AT ____________
TOTAL TIME ____________ (minutes)

---

1. SELECTS PARTS FOR TURNING PART

Correct Parts Omitted

☐ metal rod
☐ 2 large wheels
☐ 2 small tubes
☐ 3 long wires
☐ sandpaper

Incorrect Parts Chosen

☐ 2 bent copper pieces
☐ 2 screws
☐ 2 washers
☐ white platform
☐ base
☐ 2 short wires
☐ 3 "L" shaped copper strips
☐ plastic ring
☐ plastic cap
☐ long plastic tube
☐ battery holder
☐ battery
☐ magnet

if correct part omitted

(1) check to see if you have all the parts you need.

(2) you left something out

(3) you left (   ) out

if incorrect part selected

(1) check to see if you have only the pieces for the (e.g., turning part)

(2) you have a part that doesn't belong

(3) you don't need (   )

TASK	CORRECT	INCORRECT					
		Error Type		Corrected Self	Assistance Given		
					Verbal		Demonstration
		Omission	Commission		told it was wrong	told how to do it	showed how to do it
2. SANDPAPERS BOTH ENDS OF THREE WIRES (approximately one inch)							
3. PUTS WHEELS ON ROD							
(a) one on each side							
(b) lined up with spokes							
4. PUTS TUBES ON ROD							
(a) one on each side							
(b) against wheels							
5. HOLDS FIRST WIRE AGAINST ROD (against long end)							
6. WINDS WIRE AROUND SPOKE							
(a) over the top							
(b) evenly and tightly							
(c) about one inch left sticking out at end							
(d) both ends of wire about same length							
7. HOLDS SECOND WIRE AGAINST ROD (against long end)							
8. WINTS WIRE AROUND SECOND SPOKE							
(a) over the top							
(b) evenly and tightly							
(c) about one inch left sticking out at end							
(d) both ends of wires about same length							
9. HOLDS THIRD WIRE AGAINST ROD (against long end)							

TASK	CORRECT	INCORRECT					
		Error Type		Corrected Self	Assistance Given		
					Verbal		Demonstration
		Omission	Commission		told it was wrong	told how to do it	showed how to do it
10. WINDS WIRE AROUND THIRD SPOKE							
(a) over the top							
(b) evenly and tightly							
(c) about one inch left sticking out at end							
(d) both wires sticking out from third spoke should be about the same length							
11. TWISTS WIRES TOGETHER							
(a) two wires from between two spokes (one from ~~end~~ each spoke)							
(b) two wires from between two other spokes							
(c) two remaining wires from between two spokes							

TUBE PART

BEGAN AT ____________
FINISHED AT ____________
TOTAL TIME ____________ (minutes)

NAME ______________________________
DATE ______________ SEX ____________
LOCATION ____________________________
CONDITION ___________________________
PROCTOR _____________________________

---

1. SELECTS PIECES FOR TUBE PART

Correct Parts Omitted

☐ 3 "L" shaped copper strips
☐ long plastic tube
☐ plastic ring
☐ plastic ~~tube~~ Cap

Incorrect Parts Chosen

☐ 2 screws
☐ 2 washers
☐ white platform
☐ base
☐ 2 short wires
☐ battery holder
☐ battery
☐ magnet

if correct part omitted

(1) check to see if you have all the parts you need.
(2) you left something out
(3) you left (   ) out

if incorrect part selected

(1) check to see if you have only the pieces for the (e.g., turning part)
(2) you have a part that doesn't belong
(3) you don't need (   )

TASK	CORRECT	INCORRECT					
		Error Type		Corrected Self	Assistance Given		
					Verbal		Demonstration
		Omission	Commission		told it was wrong	told how to do it	showed how to do it
2. PUTS THREE COPPER STRIPS ON TUBE							
(a) "L" of all three copper strips at same end							
(b) copper strips separated by ridges							
3. PUTS RING ON TUBE (against "L" of copper strips)							
4. PUTS CAP ON TUBE (covers ends of all copper strips)							

BASE PART

BEGAN AT ____________

FINISHED AT ____________

TOTAL TIME ____________ (minutes)

NAME ____________

DATE ____________ SEX ____________

LOCATION ____________

CONDITION ____________

PROCTOR ____________

---

1. SELECTS PARTS FOR BASE

Correct Parts Omitted	Incorrect Parts Chosen
☐ 2 screws	☐ 2 short wires
☐ 2 washers	☐ battery
☐ white platform	☐ battery holder
☐ base	☐ magnet
☐ 2 bent pieces of metal	

if correct part omitted

(1) check to see if you have all the parts you need.

(2) you left something out

(3) you left ( ) out

if incorrect part selected

(1) check to see if you have only the pieces for the (e.g., turning part)

(2) you have a part that doesn't belong

(3) you don't need ( )

TASK	CORRECT	INCORRECT					
		Error Type		Corrected Self.	Assistance Given		
					Verbal		Demonstration
		Omission	Commission		told it was wrong	told how to do it	showed how to do it
2. ATTACHES PLATFORM TO BASE							
(a) put on correct end of base							
(b) put on in correct position							
(c) prongs from base bent over onto platform							
3. ATTACHES BENT PIECE OF COPPER TO PLATFORM							
(a) screw through washer, then through hole in bent piece of copper							
(b) screw, washer, and piece of copper put on base with screwdriver							
(c) long end of piece of copper toward center of platform							
4. ATTACHES SECOND PIECE OF COPPER TO PLATFORM							
(a) screw through washer, then through hole in bent piece of copper							
(b) screw, washer, and second piece of copper on base							
(c) long end of piece of copper toward center of platform							

BEGAN AT ____________
FINISHED AT ____________
TOTAL TIME ____________ (minutes)

CONNECTING MAJOR PARTS

NAME ____________________________
DATE ______________ SEX ____________
LOCATION ____________________________
CONDITION ____________________________
PROCTOR ____________________________

	CORRECT	INCORRECT					
		Error Type		Corrected Self	Assistance Given		
					Verbal		Demonstrati
TASK		Omission	Commission		told it was wrong	told how to do it	showed how to do it
1. **PUTS** TUBE ON TURNING PART (bent ends of tubes facing spokes)							
2. **LINES** UP BENT ENDS OF TUBE BETWEEN SPOKES							
3. **WRAPS** TWISTED WIRES AROUND METAL STRIPS ("L") (wires from between spoke wrapped around metal strip between same spokes)							
4. **INSERTS** ENDS OF METAL ROD THROUGH HOLES IN **UPRIGHT** PIECES (tube is between bent pieces of copper on platform)							
5. **SLIDES** EACH BENT PIECE OF COPPER AGAINST TUBE AND **TIGHTENS** SCREWS							
6. **PUTS** MAGNET ON BASE (edge fits into slits in platform)							
7. **SANDPAPERS** ENDS OF WIRES (about one inch of each end of short wires)							

	CORRECT	INCORRECT					
		Error Type		Corrected Self	Assistance Given		
					Verbal		Demonstration
TASK		Omission	Commission		told it was wrong	told how to do it	showed how to do it
8. ATTACHES SHORT WIRES TO BENT COPPER PIECES (a) through holes in bent pieces of copper							
(b) wrapped tightly							
9. ATTACHES WIRES TO BATTERY HOLDER (a) through holes in upright pieces of metal							
(b) wire wrapped tightly							
10. STARTS MOTOR (battery in battery holder)							